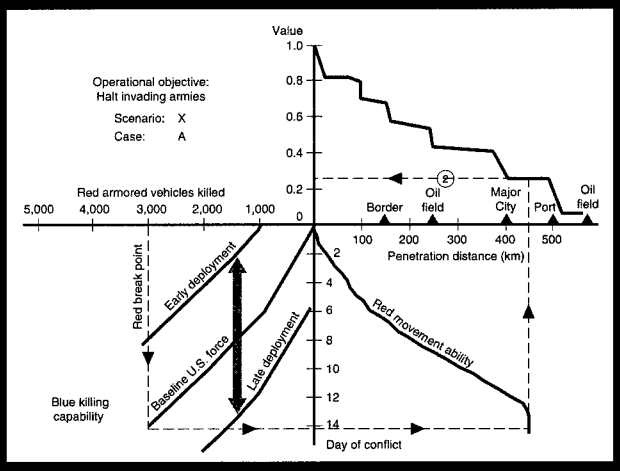
A Tool for Evaluating Force Modernization Options



TIM BONDS · GLENN A. KENT · COLIN LAMPARD · RANDALL BOWDISH
JOHN BIRKLER · MONTI D. CALLERO · JAMES CHIESA

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NATIONAL DEFENSE RESEARCH INSTITUTE
RAND

PREFACE

This report presents a tool for evaluating force modernization packages to meet future military capability needs. The research was accomplished over an eight-week time span in support of the Quadrennial Defense Review. The resulting report should be useful for those within the Office of the Secretary of Defense and within the services who are concerned with evaluating modernization options. This research was conducted as part of the study entitled "Setting Modernization Priorities." The study was conducted within the Acquisition and Technology Policy Center of RAND's National Defense Research Institute, a federally funded research and development center supported by the Office of the Secretary of Defense, the Joint Staff, the unified commands, and the defense agencies.

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SUMMARY

Developing operational concepts and investing in the related systems and manpower have always caused contention. It is more contentious and uncertain to make these choices when, as in the present, the following trends are apparent:

- The international environment has changed, causing fundamental changes in the nature or relative emphasis of military operations and in the needs for new capabilities.
- Major systems are reaching the end of their lives, forcing decisions to modernize or eliminate particular force structures.
- Innovations in technology and doctrine are emerging, offering opportunities for dramatic improvements in military capabilities.
- Budget tightness necessitates that new forces provide a flexible range of capabilities as a hedge against uncertainty and that these capabilities be delivered in a more efficient way.

In times like these, the *process* of making modernization decisions should also be reviewed. With major changes occurring in systems, forces, and the way those forces are used, force modernization proposals must be evaluated against an integrated set of future operational objectives and capability needs.

We believe that, from the point of view of the Under Secretary of Defense (Acquisition and Technology)—the principal advisor to the Secretary on force modernization—the modernization process may be usefully conceptualized as consisting of five elements:

- Defining military missions to attain desired national ends.
- Establishing the value of alternative mission outcomes.
- Examining a range of scenarios to identify where military capability shortfalls exist.
- Developing operational concepts to supply the needed military capabilities.
- Evaluating alternative force modernization packages that incorporate new operational concepts, to determine the best opportunities for supplying the needed military capabilities.

Together, these elements constitute an iterative system with assumed national ends, missions and objectives, and values of outcomes, as well as contemplated campaigns requiring inspection and change. In this report, we describe this system in some detail, focusing on evaluation. For that element, we provide an analytic tool to help integrate value of mission outcome, military capability shortfalls, and new operational concepts. The tool is part of a larger methodology that includes metrics to analyze many scenarios, to calculate possible outcomes given variations in important variables, and to determine how alternative force modernization packages can improve outcomes.

The tool we propose is the nomograph—a method of graphic analysis often used in economics and engineering. Nomographs (also known as nomograms) use two or more quadrants of the standard Cartesian four-quadrant graph. However, what would in a standard graph be the negative segments of the vertical and horizontal axes becomes axes for third and fourth metrics, beginning with zero at the origin and becoming more *positive* as the axis runs to the left (or down). This permits easy visualization of sets of relations in which, for example, z may be a function of y, y a function of x, and x a function of w (or z a function of y, and y and w both functions of x). Nomographs thus allow evaluation of alternative force packages against a common set of metrics.

Figure S.1 shows a nomograph of the sort that we propose. This example pertains to an operational objective of halting invading armies, specifically halting an Iraqi invasion of Kuwait and Saudi Arabia (a well-worn scenario, but sufficient for illustrative purposes).

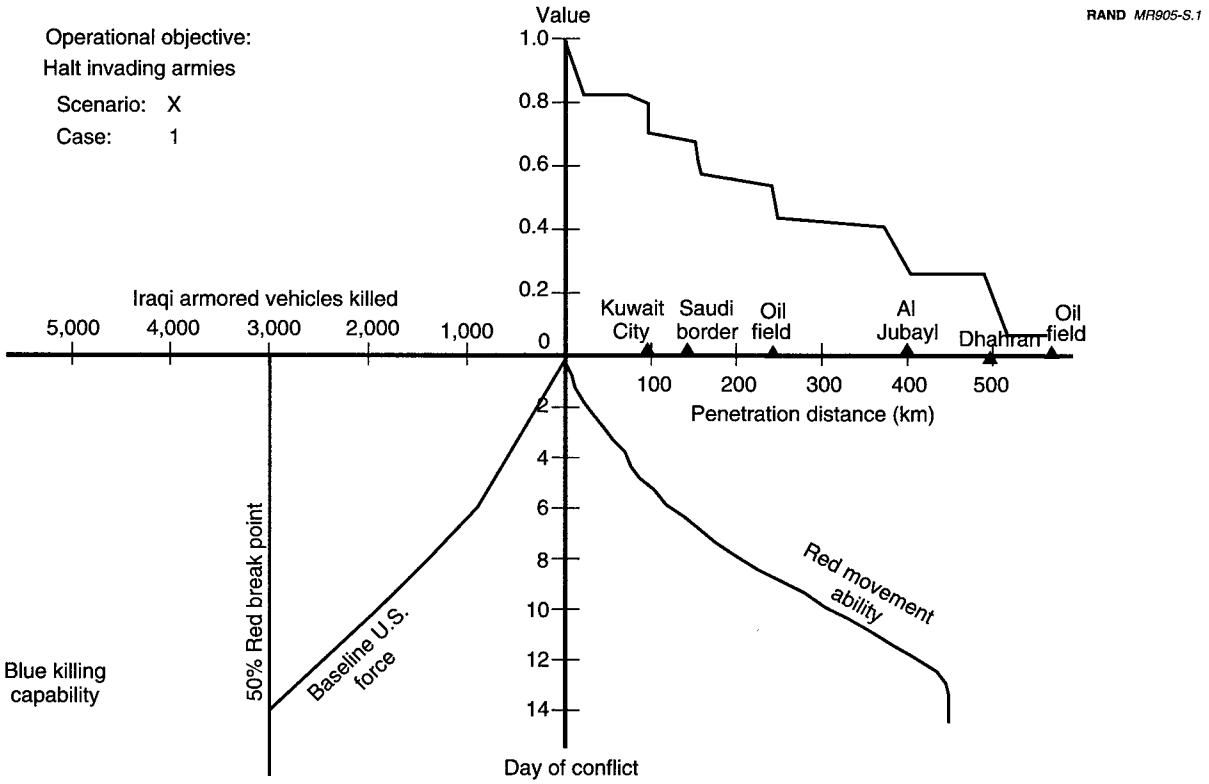

Figure S.1—Exemplar Nomograph to Assess Ability to Halt Invading Armies

The upper-right quadrant ascribes a value to penetration distance. The lower-right quadrant graphs penetration distance as a function of time, assuming no ground challenge. The lower-left quadrant depicts the number of Iraqi vehicles killed by current or already programmed U.S. forces, as a function of time. It is hypothesized that, when 50 percent of Iraqi armored vehicles (~3,000) are disabled, the Iraqi advance will be halted. As the nomograph shows, that number will not be reached until day 14, by which time the Iraqi force will have advanced over 400 km, an outcome with a low value to the United States.

The effects of incorporating new operational concepts and force modernization packages can be added to this nomograph. For example, improved U.S. capability to attack logistics and transportation infrastructures could slow down the Iraqi advance, shifting the curve in the lower-right quadrant to the left and resulting in less penetration and a higher U.S. value of outcome when the attack is halted at 14 days. Or, the lethality of U.S. strike forces might be increased, shifting the curve in the lower-left quadrant to the left so that the invasion-breaking 50 percent kill point is reached earlier, again resulting in less penetration and a higher value of outcome. In addition, the results of enemy countermeasures to new U.S. operational concepts can also be graphed.

The nomograph approach translates operational analysis into assessment of mission accomplishment, depicting the implications of U.S. force modernization packages and enemy countermeasures for achievement of U.S. operational objectives. However, not all important evaluation metrics are amenable to nomograph representation. Those not amenable include budgetary cost of the modernization packages, U.S. casualties, collateral damage to civilians and civilian facilities, damage to U.S. and allied installations, commitment of manpower resources, the opportunity cost of weapon system use, and the interoperability of modernized U.S. forces with allied forces. By combining the value enhancement information from the nomograph approach with that from other metrics, evaluators can provide top-level decisionmakers with a quantitatively sound basis from which to determine the allocation of resources most consistent with achieving a given objective.

ACKNOWLEDGMENTS

We are grateful to our sponsor, Nancy Spruill, Deputy Director, Acquisition Resource, for her candor, guidance, and support through the course of this research.

We are also indebted to RAND colleagues Giles Smith and Paul Davis, who have added considerably to the form and content of this work throughout its development. Past research by Glenn Kent, David Thaler, and John Bordeaux also contributed much to our thinking about value functions, and the criteria for choosing critical missions and objectives. John Bordeaux, Gary Liberson, Bruce Davis, and David Ochmanek contributed exemplar analyses from other RAND research to illustrate the use of nomographs. Finally David Ochmanek, Alan Vick, Gene Gritton, and Dick Hundley contributed much during the course of our work in conversations and critical reviews. Without the help of our colleagues at RAND, this work would have been impossible.

Chapter One

INTRODUCTION

THE WHY AND HOW OF FORCE MODERNIZATION

The modernization of U.S. military forces is an ongoing process and one that will continue into the near future and beyond. There are several reasons for this:

- The international environment has changed, causing fundamental changes in the nature or relative emphasis of military operations and in the needs for new capabilities. It has thus been argued (Davis, 1994a) that force planning should focus on environment shaping and on operational and strategic adaptiveness. Such ideas are central to the new strategy of "shape, respond, prepare now" described in the Department of Defense (DoD) Quadrennial Defense Review (Cohen, 1997).
- Major systems will soon reach their end of life—forcing decisions to modernize or eliminate some force structures. Such systems, e.g., tactical aircraft, are often purchased—and hence are eventually retired—in large blocks.[1] Funds are typically unavailable to replace these retiring systems one for one. By modernizing operational concepts, systems may be replaced at fewer than one for one and not cause a corresponding loss of capability.
- Innovations in technology and doctrine offer opportunities for dramatic improvements in military capabilities. According to the national security strategy (Clinton, 1997; see also Cohen, 1997),

[1] See Lewis (1994).

> we must prepare now for tomorrow's uncertain future. This requires . . . evolving our unparalleled capabilities to . . . shape and respond to meet future challenges. Key to this evolution is the need to foster innovation in new operational concepts, capabilities, technologies and organizational structures.

- Budget constraints necessitate that new forces provide a flexible range of capabilities as a hedge against uncertainty and that these capabilities be delivered more efficiently. Khalilzad and Ochmanek (1997) observed that "it is less and less possible to hedge against uncertainty by fielding redundant capabilities." Davis, Hillestad, and Crawford (1997) suggest finding concepts of operation to accomplish the same warfighting job with fewer forces, to increase the probability of success (e.g., through hedging against severe air defenses), or to shorten wars and decrease the amount of casualties.

To modernize military forces, resources must be allocated among new operational concepts and methods for implementing them. Resource allocation methods within DoD have been well documented elsewhere. Notably, Kent and Simon (1994) have abstracted from the complex, iterative modernization process an idealized, linear, functional paradigm that will be of particular use to us in this report.[2] The steps in this paradigm are as follows:

1. Define missions and establish values of outcomes. The Secretary of Defense and the Chairman of the Joint Chiefs of Staff, with the help of the Office of the Secretary of Defense (OSD) and the Joint Staff, are responsible for defining the principal missions to be accomplished by U.S. military forces, consistent with the strategic goals set forth by the president. Together with the combatant commanders and other members of the operational community, these top-level decisionmakers also identify specific operational objectives that must be achieved to accomplish these missions. They identify which objectives are most critical and determine the value of each alternative outcome for each critical mission and objective. Persons acting in this capacity—decisionmakers, their staffs, and others—are sometimes called "strategists."

[2]See also Kent (1983), and Kent and Thaler (1993).

2. Identify deficiencies in military capabilities. Strategists also identify deficiencies in current or planned military capabilities that should receive priority attention. Here, the focus should be on increasing operational capabilities in an economically and militarily feasible way, instead of attempting to identify firm "requirements" (Davis, 1994a).

3. Conceive and develop concepts to provide new capabilities. The research and development communities—including organizations within DoD, the services, and civilian industry—are responsible for developing new concepts to provide needed capabilities. New operational concepts arise from an understanding of emerging technologies, doctrine, the operational realities that military commanders face, and the overall strategic environment, including evolving threats. New concepts must be technically feasible, operationally viable, politically acceptable, and fiscally sensible. New concepts meeting the above criteria provide an opportunity to resolve deficiencies in military capabilities. Promising new operational concepts are included in alternative force packages and submitted as "bids" to provide the capabilities needed. We use the term "conceivers" to apply to persons carrying out this third modernization function.[3]

4. Evaluate modernized force packages to help decisionmakers choose which to purchase. Top-level decisionmakers, with the advice of the research and development and operational communities, ultimately must choose which modernized force packages to purchase and which new operational concepts to support. Choosing among options requires evaluating the abilities of alternative force packages and operational concepts to improve the outcome for a given mission or operational objective. Costs need to be considered; implications for required manpower and training need to be delineated; the applicability of resulting packages to multiple missions need to be determined; and judgments about the relative importance of various tasks and missions need to be made. We use the term "evaluators" for those who carry out this final function for presentation to top-level decisionmakers.

[3]Like "strategist," the term "conceiver" refers to a role, not a specific position. The same individual may be a strategist when fulfilling some of the duties required of his or her position and a conceiver when performing others. The same applies to "evaluators" below.

Note that the real-world force modernization process is more complex than this four-step paradigm suggests. Planning is not top-down, linear, and deductive, but a hierarchical, nonlinear, and iterative process of judging how much is enough—in aggregate terms, in intermediate terms, and in detailed terms. Further, there is frequent revisiting of the issues, because priorities change.

PURPOSE OF THIS STUDY

Military resource allocation choices are often contentious, especially when—as now—international events and domestic budgets require significant changes in the character and capabilities of U.S. military forces. With major changes occurring in systems, forces, and the way those forces are used, it is more important than ever that new concepts be evaluated against an integrated set of capability needs based on future missions and operational objectives.

In this report, we present a tool to help decisionmakers, concept developers, and operators integrate objectives and capabilities, note deficiencies, and offer solutions or compromises. This tool will

- make explicit the values associated with possible outcomes of an operation (usually these values are only implied in analyses and decisions)
- introduce a common set of metrics to judge the contribution of alternative force packages in improving outcome value
- reflect the threat posed by the forces and actions of adversaries, and how the United States might counter them.

The tool we have chosen to accomplish these objectives is the nomograph. The set of nomographs that we present integrates quantitative expressions of objectives, options, outcome measures, and costs. Each nomograph is developed for a specific mission and operational objective within a specific contemplated contingency. For other missions, operational objectives, and contingencies, new nomographs would need to be drawn.[4]

[4]This might seem to require endless numbers of nomographs, but broad screening analysis in a "scenario space" of cases can identify good test cases (Davis, 1994a;

In Chapter Two of this report, we describe how strategists identify critical operational objectives. We choose two objectives to illustrate the application of the nomograph tool and describe, for those exemplars, how strategists establish the values of outcomes and how they assess the threats posed by enemy forces.

Chapter Three describes the process of how conceivers develop new operational concepts and how evaluators determine the contribution of these concepts as part of a modernized force package. The quantitative data are not intended to show definitive force analyses results. Rather, they are useful to demonstrate the construction and use of our nomographs given quantitative analyses at the engagement and operational levels. These data are presented with generic descriptors, and with some of the numerical information removed to protect sensitive results.

Chapter Four integrates the results of the previous two chapters on nomographs and shows how the modernized force packages can improve outcome value for our two illustrative examples. Chapter Five then shows how evaluators can use the results of this analysis to inform modernization decisions and discusses additional factors that may affect evaluators' recommendations about which packages to acquire. The final chapter offers a few concluding observations and suggests directions for further work.

Davis, Hillestad, and Crawford, 1997). The nomographs can then focus on these test cases.

Chapter Two

IDENTIFYING MISSIONS, VALUES OF OUTCOMES, AND DEFICIENCIES IN MILITARY CAPABILITIES

In this chapter, we describe what strategists contribute to the force modernization process: a clearly articulated "demand" for military capabilities.

Establishing the demand includes deciding, at a national level,

- what goals, missions, and objectives are important and which are critical to the nation
- how alternative outcomes should be valued
- how far short U.S. forces might fall from a desirable outcome given known or contemplated threats.

The demand articulated by strategists is intended to motivate development of end-to-end operational concepts that achieve important operational objectives in an affordable way. Strategists provide rough guidance on values and on "how much is enough." Decision-makers use this information to make trade-offs that have the effect of determining more precisely what is needed, and thereby specifying demand within the spirit of the guidance. Ideally, a competition among concepts would follow, including assessments of the real contribution of alternative modernization options.

Clearly, establishing the demand does not entail identifying solutions—those will be developed separately, by many different organizations (conceivers) advocating disparate approaches to satisfying the demand. Statements of demand should thus not be oriented to-

ward specific military services—they should be "agnostic" as to which services might provide what types of solutions. This helps foster an environment in which the best solutions may surface.

If strategists have not provided clear guidance on important missions and objectives, then the research and development and operational communities will be tempted to fill the vacuum, concentrating on *how* rather than *what*—an undesirable situation. (This situation occurs to a lesser degree whenever strategists have been unclear as to which missions are most critical, what the values of outcomes are, and what deficiencies exist. In such situations, where guidance is available but some of the particulars need to be filled in, the temporary, ad hoc "filled" pieces provided by operators or developers will be valuable for debate and for initiating concept development.)

DETERMINING CRITICAL MISSIONS AND OBJECTIVES

The national security strategy from the president, as well as other statements of policy, defines the strategic vision within which critical missions and objectives are identified. The defense planning guidance and the national military strategy support and extend that vision. The recent national security strategy lists three elements of an integrated approach to countering threats to U.S. interests: shaping the international environment, responding to crises, and preparing now for an uncertain future (Clinton, 1997; Cohen, 1997). Currently, the national military strategy defines two national military objectives: Promote stability and thwart aggression (Shalikashvili, 1995). Missions given to the combatant commanders in support of these objectives are shown in Figure 2.1 (derived from Ochmanek and Hosmer, 1997).

Within a contemplated contingency, each of the missions shown is supported by one or more operational objectives. For example, in a contemplated conflict against an aggressor in Southwest Asia, the Commander in Chief, U.S. Central Command (CINCCENT) may be given the mission to deter and defeat aggression against Saudi Arabia and Kuwait. To accomplish this mission, CINCCENT may determine that several specific operational objectives are critical to accomplishing the mission, e.g., halting invading armies, neutralizing enemy air

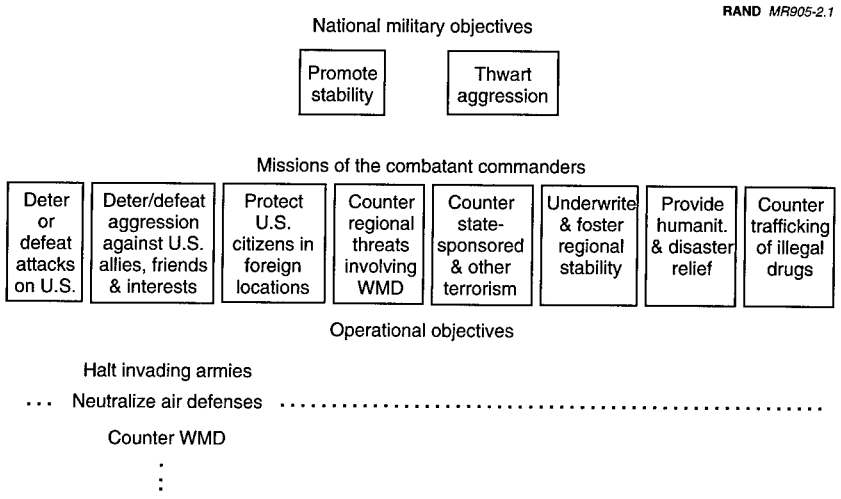

Figure 2.1—Missions and Critical Operational Objectives

defenses, countering the enemy's weapons of mass destruction (WMDs).[1]

ESTABLISHING VALUE OF OUTCOME

The next steps in determining the demand for military capabilities are to identify the mission outcomes desired by the United States and to show how highly they are valued. The concept of value transcends purely military considerations and should reflect the security of the people and institutions of the United States, other interests, and basic humanitarian concerns. The concept of value has always been implicit in modernization-planning analyses of force sizing, force structure, and readiness decisions. The tool we propose in this report will help make value a more explicit factor in planning.

[1]Such determinations should recognize the massive uncertainties involved. Davis (1994b) argues that one must "reconceptualize planning to more seriously confront the issue of uncertainty." He emphasizes that the strategist should discard the illustrative scenario and adopt a "scenario space" methodology. Later work (Davis, Hillestad, and Crawford, 1997) describes an analytic methodology in which classes of scenarios are studied together with key factors, such as access and deployment times; the factors are then varied and the effects noted.

Outcome values should reflect credible interpretations of what is fundamentally important to national interests and should stand serious scrutiny and debate. There should be a clear audit trail to their origin to enable their interpretation and modification as needed. Clearly, value is dominated by human judgment—so determination of value must be addressed as a *subjective measurement process.* Fortunately, there are well-established subjective measurement methods available that can be applied to the task.[2]

Mission and operational objective outcomes may be given a low value because they decrease U.S. ability to achieve the national security strategy approach of "shape, respond, prepare now" or the national military objectives of promoting stability and thwarting aggression. Costs imposed by conflicts may also be reflected in the values of outcomes. For example, minimizing casualties may be a part of this value. If the United States suffers casualties out of proportion to the stakes it has in a conflict, the resulting value of the outcome will be low.

What functions do we use to relate value of outcome to the details of the outcome? We need value functions that reflect national concerns, such as protecting critical areas and minimizing casualties. The value functions should be inputs of the ultimate resource allocation and strategic decisionmaking. Also, choices about value strongly affect military objectives, and eventual changes in objectives may be caused by value changes.

USING VALUE OF OUTCOME TO IDENTIFY DEFICIENCIES

In the planning environment, combatant commanders and others develop contingency situations that describe a possible adversary's best courses of action (those most difficult for friendly forces to counter) or his most likely courses of action (given what is known or assumed about his training and doctrine). These contingency descriptions are used to prepare military plans to counter these contingencies and to identify *deficiencies* in U.S. operational capabilities.

[2]For discussions of subjective judgment, see, e.g., Bell, Keeney, and Raiffa (1977); Kahneman, Slovic, and Tversky (1982); and Veit and Callero (1995), who describe applications to military problems.

A contingency can be described as a collection of possible events and outcomes, each of which has an effect on U.S. national interests and the level of value attainable. For example, the United States values its ability to shape events in important parts of the world. If an attack is prosecuted against important allies, such as Kuwait and Saudi Arabia, then the United States has already lost some value because deterrence has failed (implying inadequate shaping of the environment or promotion of stability). Further value will be lost as the United States and its allies incur casualties, and as the aggression appears to achieve some measure of success. Subsequent ability to respond in a way that denies the enemy ultimate success will also affect the eventual value of outcome achieved.

An **event-based value function** is formed by placing each event in a sequence on the abscissa (x-axis) and its associated value on the ordinate (y-axis). Events are ordered on the abscissa so that values either increase or decrease monotonically. Figure 2.2 is a notional example of an event-based value function in which we have connected the event values with a line segment so the shape of the value pattern is more discernible (in this figure, value decreases along the abscissa).

Several features of this value function should be noted. First, value is a function of a specific scenario and case. This means that one needs to understand how some contingency impacts the security or interests of the United States, and hence the missions that might be given to a CINC. The value function can then be constructed for the mission as a whole or for each critical operational objective.

Second, the value function depends on some event or set of events taking place. The events could result from friendly action, exogenous events, or the activities of a hostile party. Examples could be the shelling of a friendly capital, penetration of a friendly border, or the loss of a critical resource. Each of these events will result in some risk to U.S. security or interests and will result in some loss in value of outcome for the mission or objective. Even if the events can be reversed, such as a loss of territory, it may be that the costs involved are themselves irreversible.

The third feature to note is implied in Figure 2.2 and captured explicitly elsewhere in the methodology. If more than one calamitous

event is contemplated, it may be that these events are connected in some important way representable by a single metric. For instance, it may be that a friendly nation loses territory and facilities as an invading army conquers territory; hence, the unifying metric is the distance the enemy army has penetrated. Or, perhaps, the enemy comes from within, using guerrillas and special forces to capture these facilities. In this case, time may be a unifying metric.

Such unifying metrics facilitate ordering of events in a sequence. Value lost as the sequence progresses can then be plotted, and the point of minimum acceptable value can be discussed. Where value falls below the minimum acceptable level, there is a deficiency in the value of outcome. This implies a concomitant deficiency in U.S. military ability to accomplish the relevant mission or operational objective.

We now describe a process for determining the values of national interest and show how an event-based value function can be calculated using the national-level values. We then describe how to use

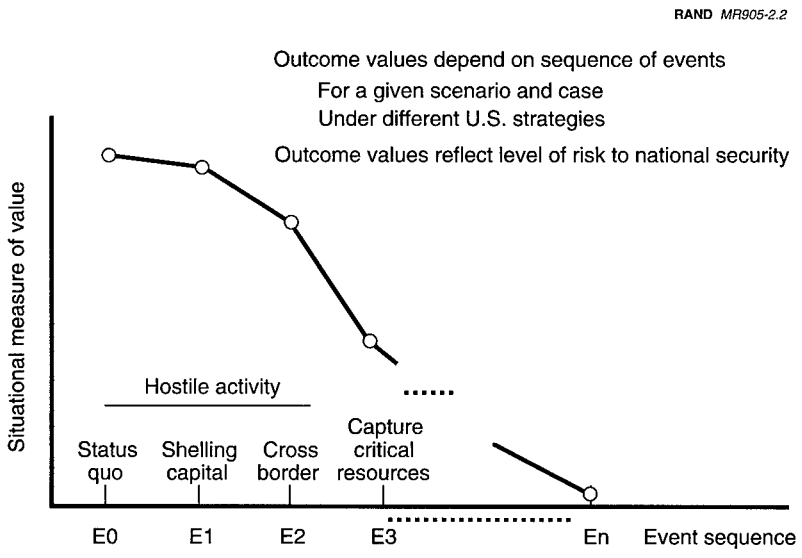

Figure 2.2—Event-Based Value Function

the event-based value function to aid in identifying shortfalls and potentially high-payoff modernization options.

EXEMPLAR CASES

For the purpose of this research, we derived an exemplar value function that reflects the elements that top strategists would need to consider. In so doing, we did not intend to precisely capture event value in either scope or scale; much additional research is needed to draw a value function more than notionally. Part of the utility of deriving the value function is to make implicit notions of value *explicit.* When value is explicit, it is easier to subject a value determination to review and to use the value function for consistently identifying deficiencies and opportunities to resolve them.

To appreciate where American interests might be most threatened, several scenarios—each with many variations on environmental, strategy, and effectiveness factors—must be analyzed. Such a "scenario space" approach has been documented elsewhere,[3] and it will not be further discussed here. For the example we chose, the mission was to deter or defeat aggression against Saudi Arabia and Kuwait, and the critical operational objective under examination is "halt invading armies." It was hypothesized that the enemy would employ armored forces to take Kuwaiti and Saudi territory, and hence the events are sequenced by the distance penetrated by the invading army.[4]

To illustrate the approach, we conducted an exercise at RAND with a number of experienced military officers. They generated the range of value functions shown in Figure 2.3. We then created a composite (Figure 2.4). If the method were used by the national leadership, of course, the curve would have to reflect the values of the nation to the extent that they can be determined.

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[3]Davis (1994a) and Davis, Hillestad, and Crawford (1997).

[4]It may seem pedestrian to once again use an armored invasion of Kuwait and Saudi Arabia as an example. We use it because people have fairly well-established, if personal, views about what value to attach to events in contemplated Southwest Asia contingencies. Also, Davis and Kugler (1997) argue that "the continued ability to win decisively the 'virtual wars,' which will not happen because the potential aggressor knows he would fail, should be a prominent and permanent U.S. objective."

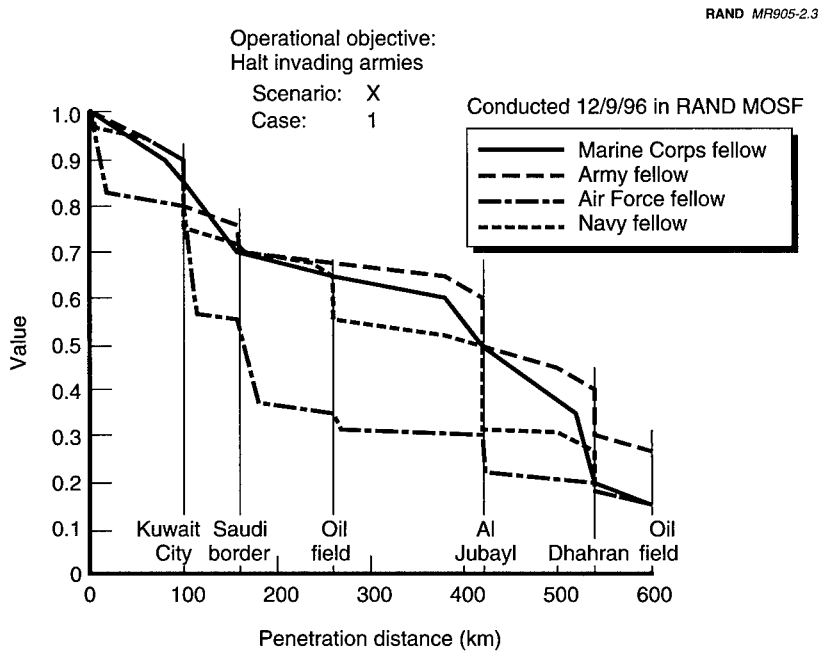

Figure 2.3—Officers from Each Service Defined a Different Value Function

The United States must recognize the enemy's potential value function—and particularly the possibility that it may not be exactly the reverse of the U.S. function. That is, completely different events may dominate the enemy's value function. The events precipitating losses to the United States may be incidental for the enemy and therefore not his chief aim.

What is valuable to the United States will be affected by what is valuable to U.S. allies. West Germany, for instance, during the cold war might have set a zero or near-zero value point if the Soviet Army took the last major German city. The West German value curve would have dropped off quickly from the time the Soviet Army crossed the border. Left to itself, with no strong alliances, the United States might have taken the larger view of Western Europe as a whole, and its near-zero value point might have corresponded to being evicted from the continent (assuming Britain remained unconquered). In

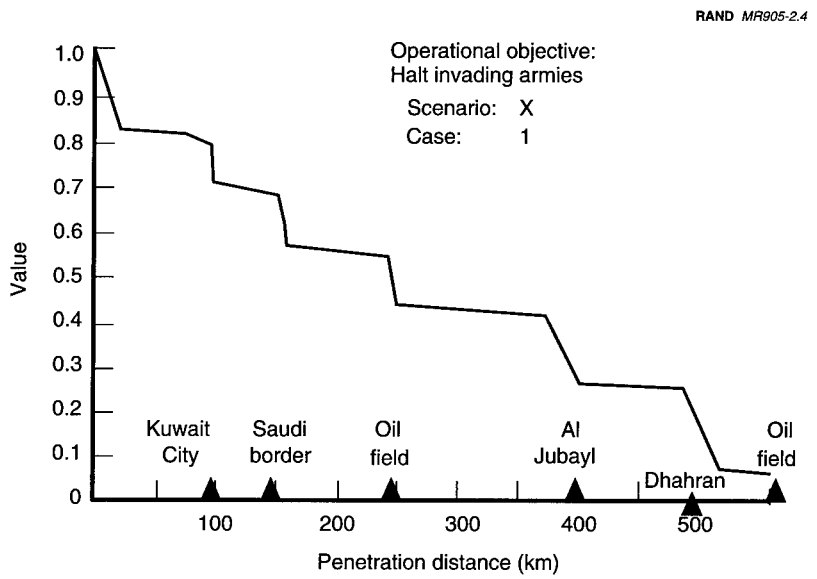

Figure 2.4—The National Command Authority, the Commander in Chief, or the Joint Task Force Commander Could Collapse Differing Curves into One Common Function

fact, however, the U.S. value function is related to the interests and objectives of critical concern to key allies (such as Germany), and this relation is evident in U.S. force deployment and employment.

Since our framework is useful for considering many other topics in addition to invading armies, we have constructed a second example for the operational objective of neutralizing enemy air defenses. This objective could be subordinate to halting invading armies in some campaigns but might also be a primary objective if, for example, a hostile nation were attempting to prevent overflight of some disputed territory.

In Figure 2.5, we depict decreasing value of outcome as the potential for U.S. aircraft attrition increases. We use potential attrition, rather than actual attrition, because the air forces would likely change the way they operate, or halt operations altogether, once attrition ap-

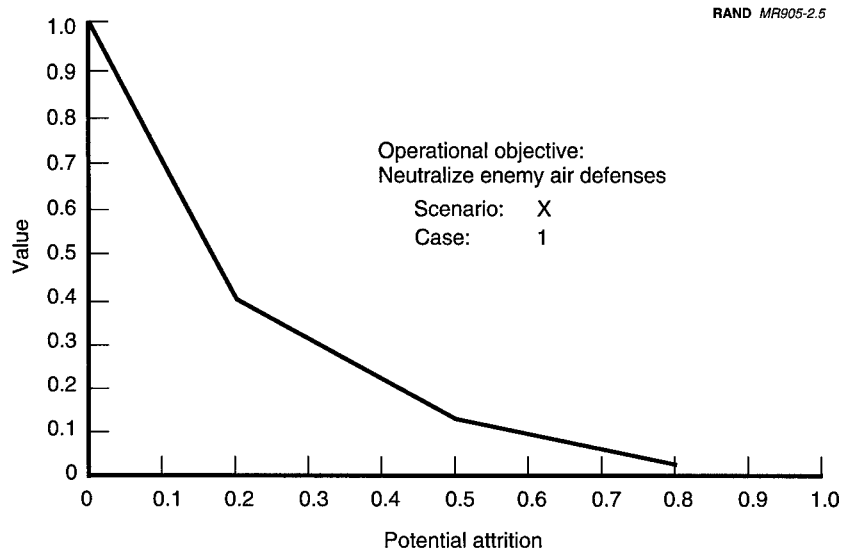

Figure 2.5—Notional Value As a Function of Potential U.S. Aircraft Attrition

proached some unacceptable level. The fact that such an adaptation is necessary in itself may cause some loss in value—because the air forces have lost flexibility, are performing less well, or are using resources (such as standoff weapons) at a greater rate.

HYPOTHESIZED THREATS

The operational community may anticipate enemy forces with the ability to threaten U.S. mission accomplishment. If we are to consider ways to mitigate the threat posed, enemy capabilities need to be hypothesized along some abscissa related to practicable U.S. operational concepts. The combination of these hypothesized threats and outcome values will help identify deficiencies in current military capabilities.

Our first example hypothesized an invading enemy army moving as shown in Figure 2.6.[5] For this example, time is the important metric affecting penetration. The Red (enemy) armored column has some capability to move forward as a function of time, terrain, logistics, and Blue (U.S. and allied) resistance. Here we have looked at that movement capability as a function of time since the initiation of hostilities.

For our second example, we plot the potential attrition of current-generation fighter aircraft against some notional surface-to-air missile (SAM) laydown (Figure 2.7). Here, the metric is not time, but the percentage of the original total of SAM sites that are committed to combat for a given sortie. Less than 100 percent may be committed,

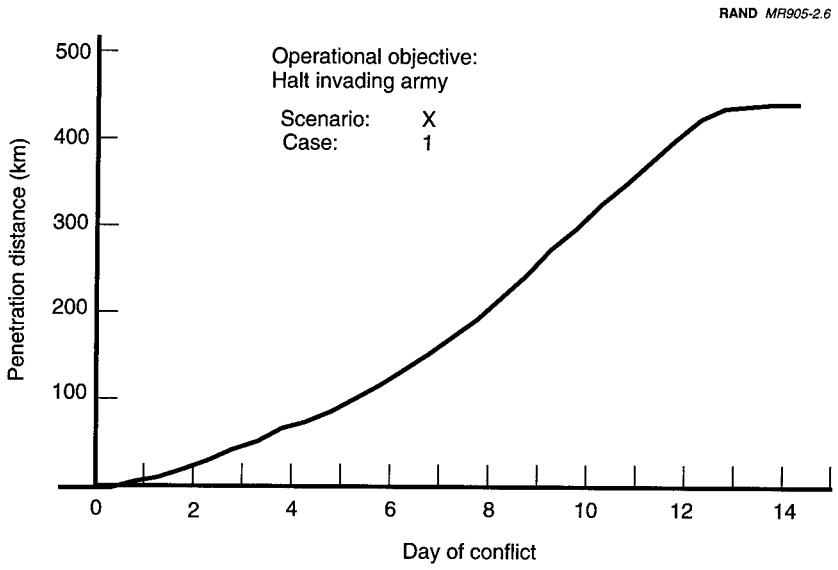

Figure 2.6—Hypothetical Enemy Movement As a Function of Campaign Time

[5]We are indebted to our RAND colleagues John Bordeaux, Gary Liberson, and Bruce Davis for providing the exemplar analyses we use here and elsewhere in this report. They were developed in research sponsored by the U.S. Air Force.

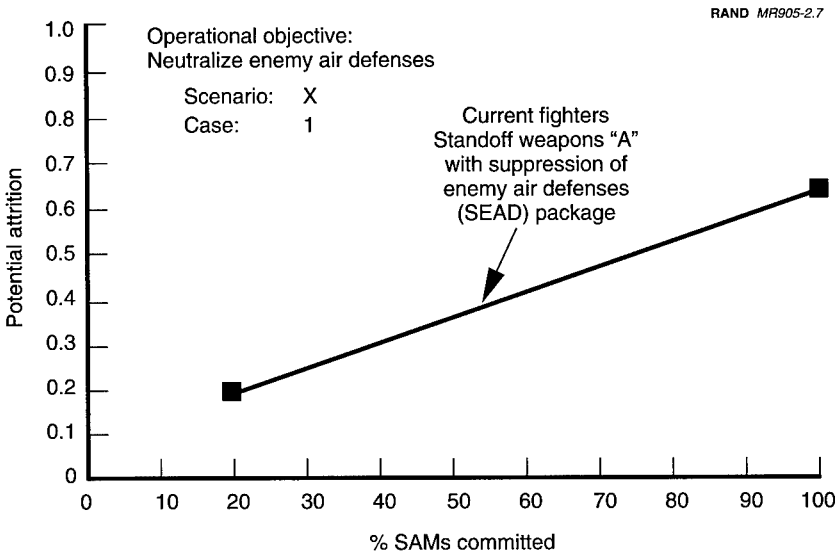

Figure 2.7—Potential Attrition of U.S. Aircraft As a Function of Enemy SAM Availability

as a result of attrition, equipment reliability, or because the Red commander has elected to employ some strategy governing their use. On any given sortie, potential attrition increases with the number of SAMs available.

Chapter Three

DEVELOPING NEW CONCEPTS AND FORCE MODERNIZATION PACKAGES

Concept development has the role of keeping the U.S. military one step ahead of the rest of the world in the development of fighting capability. Conceivers come from the services, defensewide organizations, and private industry and draw on people from the research and development and the operational communities. The vision of concept development differs from strategy formulation in that it focuses on the *means* rather than the *ends*. Concept development includes the difficult tasks of envisioning how war will be fought in the future and developing *winning* war-fighting concepts for that future. It entails discerning the most promising paths for concept development, given a host of potential combinations and permutations of an uncertain future world.

PROCESS

Taking account of demand (i.e., critical objectives, values of desired outcomes relating to those objectives, and military deficiencies that should receive priority), concept developers

- survey the state of the art of various technologies—both existing and emerging—and interact with the operational community to understand potential applications
- develop new operational concepts that possess certain functional capabilities and performance features
- assemble these concepts into force modernization packages

- propose demonstrations of selected systems and end-to-end operational concepts.

New operational concepts that show promise should be

- technically feasible—i.e., all of the technologies should have been demonstrated sufficiently—additional development should not be necessary before an acceptable level of technical risk is obtained
- operationally viable—i.e., the risk of casualties, the amount of time needed to achieve the objective, the number of forces needed to implement the concept, etc. should be within some reasonable bounds
- acceptable from a policy point of view—i.e., their employment should be consistent with U.S. interests, values, and beliefs
- affordable—i.e., likely to be funded given the scarcity of resources and other worthy uses.

New operational concepts meeting these criteria may provide an *opportunity to resolve deficiencies* in operational capabilities.

Operational concepts include the platforms, weapons, doctrine, trained personnel, and supporting systems developed to accomplish a specific task. An example is personnel on board a command ship, using data acquired by off-board sensors, directing the fire of antitank munitions from an arsenal ship, in order to destroy the leading elements of an invading armored column. A new operational concept might reflect innovations in any of these constituent elements.

One or more operational concepts can be formed into a force package to achieve some operational objective. An example of a force package is the combination of air-, sea-, and ground-based forces that together are tasked to halt an invading army. Evaluations of the new operational concepts then are performed in the context of the improvement in the force package's ability to achieve the intended objective.

EXEMPLAR CASES

For the purpose of our first example, assume that conceivers have employed a variety of analytic techniques to estimate the ability of existing operational concepts to kill enemy armored vehicles under a variety of conditions. Performance analyses of individual systems, "few-on-few" and "many-on-many" engagement analyses against adversary systems, and campaign analyses may have been performed with new concepts that are part of a larger force package.

The killing potential of the baseline force package in a campaign analysis is a function, for example, of the following: cumulative time since the initiation of hostilities, forces existing in-theater at the beginning of the conflict, the deployment rate of new forces to the theater, the numbers and effectiveness of forces and equipment. The forces associated with existing operational concepts would set the baseline for examining new operational concepts. Their killing capability might be as shown in Figure 3.1.

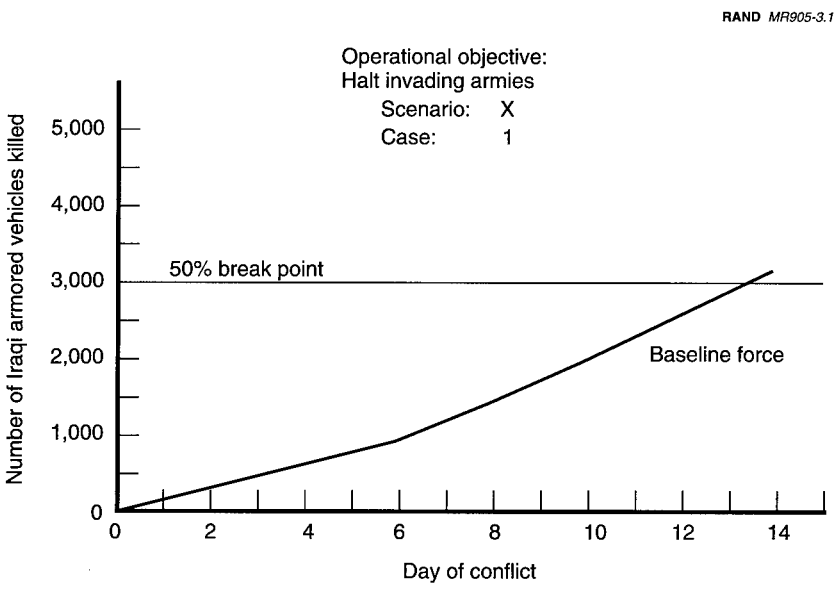

Figure 3.1—Expected Killing Capability of Baseline U.S. Forces As a Function of Campaign Time and Hypothesized Enemy Break Point

Is the killing capability estimated to be sufficient, excessive, or deficient? Let's imagine that during a subsequent evaluation of this baseline force package, some members of the operational community, perhaps the combatant commanders, determine that this killing capability is deficient. For example, the conceivers might be told that they need to kill approximately 50 percent of the Red armored vehicles to halt the offensive. It is estimated that this can be done by day 14 of the conflict, given a host of assumptions of the nature discussed above. However, it might be desirable to halt the offensive earlier, before it can penetrate deep into friendly territory—how can this be done?

Each conceiver might work on a different approach, e.g., ways

- of detecting enemy intent earlier, thus allowing more time to get forces into the theater
- to speed the deployment itself
- to allow more forces to be prepositioned, making them available early in the fight
- to increase the killing capability of the current forces
- to slow down the Red armored forces, thus preventing them from reaching their objectives on day 14.[1]

As an example, let's consider efforts to kill enemy armored vehicles earlier in the conflict. The conceivers develop new operational concepts to kill these forces earlier. The new concepts need to consider how the forces will deploy to the theater, how they will find their targets, what weapons they will use on the targets, how they will survive the operation, and how they will be sustained to fight again.[2] Concepts would likely emerge using air-, ground-, sea-, and space-based systems to perform or aid some portion of the task.

The result might be as shown in Figure 3.2, where the baseline force can be augmented by developing concepts A, B, C, D, or any combi-

[1]Work by Davis, Gompert, and Kugler (1997); Davis, Hillestad, and Crawford (1997); and Davis and Carrillo (1997) presents the effect of varying contextual variables (such as warning times) and force-effectiveness variables.

[2]See Kent and Thaler (1993).

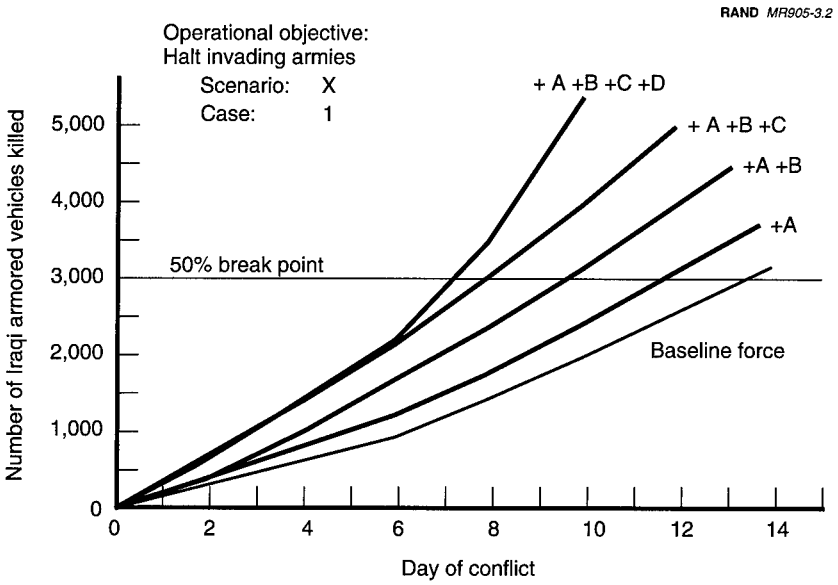

Figure 3.2—Expected Killing Capabilities of Alternative U.S. Force Packages

nation thereof (for simplicity, the only combinations shown are cumulative). Here, concepts A and C are available on the first day of the war, and each increases the killing capability of the baseline forces between 20 and 30 percent. Concepts B and D are either not available immediately, or do not have an immediate impact on the effectiveness of U.S. forces. After some point in the campaign has been reached, concepts B and D have a noticeable impact, increasing effectiveness by 50 to 70 percent.

It must be stated here that calculations such as these involve many assumptions, are highly sensitive to changes in those assumptions, and cannot be depended upon to accurately reflect how real-life operations, with real troops under real commanders, will fare. The contribution of these types of calculations has been to show how major factors—such as deployment rate or warning time before the initiation of hostilities—can affect outcome. Here we do not pretend that we can precisely calculate how fast U.S. forces can kill enemy

armor. Rather, we are attempting to determine only whether a force modernization package has any noticeable effect and, if so, its general magnitude.

In the same way, the conceivers might also investigate ways of improving U.S. forces' suppression of enemy air defenses (SEAD). Enemies might employ air defenses to deny U.S. forces the use of disputed air space or to defend invading armored units against U.S. air attacks. If U.S. forces engaged in a SEAD campaign, the number of SAMs available to the enemy would decrease as the campaign progresses. Better SEAD concepts would reduce the number of enemy SAMs more quickly.

As an example, suppose that an adversary had an integrated air defense system composed of very capable SAM systems. On the first day of the campaign, he may have all of these systems available—if they are in good repair. As the campaign progresses, U.S. forces may destroy or otherwise disable these systems. An aggressive SEAD campaign might result in the number of SAMs available dropping to only 20 percent of the original number by day 9 of the conflict (Figure 3.3).

Improved SEAD might reduce the actual or effective SAM availability more quickly than shown above. Such concepts might include improved methods of identifying and targeting the SAM systems, more powerful weapons with a larger lethal area, or nonlethal methods such as better radar jamming. Alternatively, the conceivers might develop ways to make friendly aircraft better able to survive in the presence of enemy SAM defenses by giving them standoff weapons, sending SEAD packages to escort them, providing them with stealth aircraft, or some combination of the above. These improvements would not affect the SAM availability but might decrease the potential attrition of the fighter aircraft as shown in Figure 3.4.

OUTPUT

The output of the conceivers is alternative force modernization packages together with systematic, quantitative estimates of the contributions each concept makes to force effectiveness in a variety of scenarios. These packages add new operational concepts to programmed forces to provide the military capabilities most needed.

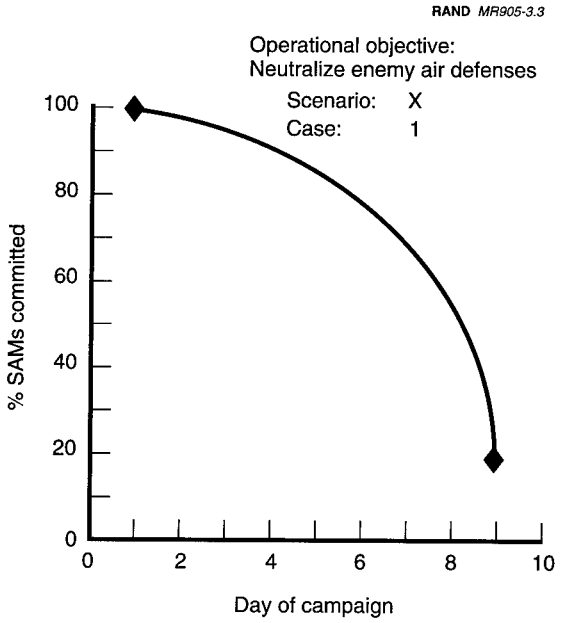

Figure 3.3—Expected Effect of Blue SEAD Campaign on Red Air Defenses

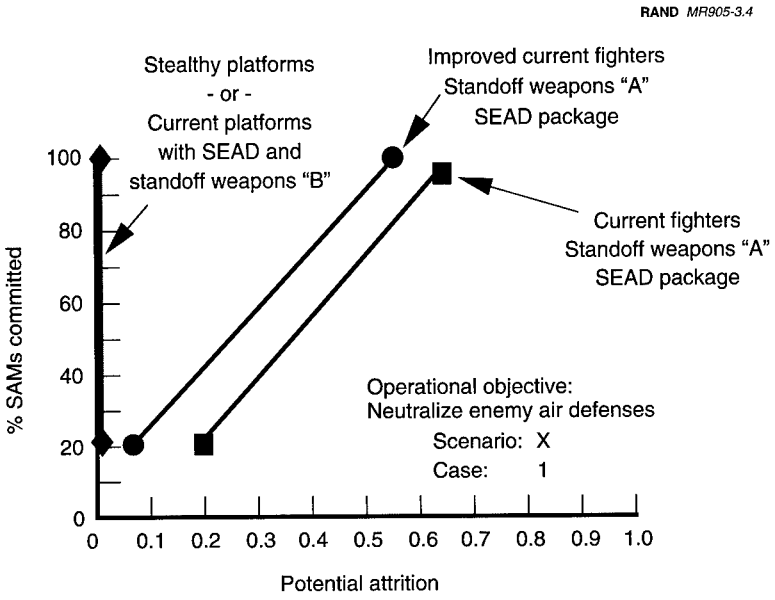

Figure 3.4—Expected Survivability of Alternative U.S. Force Packages As a Function of Enemy SAM Availability

Chapter Four

EVALUATING FORCE MODERNIZATION PACKAGES AGAINST CAPABILITY NEEDS

There will likely be more good force modernization proposals than resources to implement them. This means that alternative force packages must be comparatively evaluated. The evaluation of modernization proposals must inherently take into account the ends (the objectives) to which those proposals are the means. They should *not* be evaluated as stand-alone ideas or systems that may contribute only to a particular service's structure or relative standing as a warfighting organization.

We undertook this research to develop some way of evaluating force packages against common metrics. In this chapter, we present a tool by which to perform these evaluations. Here, the modernization packages are assessed in terms of the extent to which they provide better outcomes (value) in critical operational objectives. In some sense, the evaluation process becomes a competitive "auction," where proposals are "bid" against capability needs. "Bids" are evaluated against how well they meet those needs, and what resources will be consumed in the process. Evaluators provide the forum for the auction and the mechanism for the bidding process. Evaluators themselves will likely include staff of top-level decisionmakers, perhaps some from the research and development community, and many from the operational community, with each service and most of the major branches represented.

Evaluators seek to attain the greatest outcome value—the greatest contribution to the ends identified by strategists—by choosing among alternative systems or courses of action within fiscal, techno-

logical, operational, and policy constraints. The input from conceivers consists of alternative force modernization packages incorporating end-to-end concepts for achieving strategists' demands.

Inputs from the operational community concerning the interaction of U.S. and enemy forces are crucial to evaluation, for several reasons:

- Operators often will have recent insights about or first-hand knowledge of the capabilities of a potential enemy and the way those capabilities might be employed. Hence, the operational community can help determine how the hostile actions of adversaries can cause losses in value of outcome.
- Operators will best understand how U.S. forces might act directly against the adversary's forces or attempt to mitigate the harm caused by hostile actions.
- Operators will have an understanding of how the adversary might attempt to degrade the effectiveness of U.S. actions.
- The operational community is the best situated to determine how force packages from conceivers would be employed to defeat enemy forces. Here, we are not looking for the contribution of specific forces—they may not be identifiable. What we want is the "rough order of magnitude" contribution of a force package over time.

THE NOMOGRAPH APPROACH

Evaluators seek to integrate the value of outcomes with the actions of U.S. and enemy forces, along with other considerations. There are some common axis metrics among the component relations that need to be integrated—penetration distance, for example, in Figures 2.4 and 2.6; day of conflict in Figures 2.6 and 3.2. Some means of graphically combining these relations might be feasible and helpful.

A chronic problem in military analysis is developing analytic displays that provide a great deal of information compactly but clearly. It is not particularly difficult to use multiple vertical axes to overlay curves on the same x-axis metric in a single-quadrant plot. However, the relations among the x- and y-axis metrics cannot be readily seen.

In this chapter, we resurrect the nomograph (or nomogram), a tool that is seldom used today but that was once a standard part of scientific and engineering work. The nomograph uses two or more quadrants of the standard Cartesian four-quadrant graph. However, what would in a standard graph be the negative segments of the vertical and horizontal axes become axes for third and fourth metrics, beginning with zero at the origin and becoming more *positive* as the axis runs to the left (or down). This permits easy visualization of sets of relations in which, for example, z may be a function of y, y a function of x, and x a function of w (or z a function of y, and y and w both functions of x).

In the following two examples, we show notional nomographs we have built to help integrate alternative modernization packages, current U.S. forces and concepts of employment, and the hypothesized forces of potential adversaries and their employment, with value of outcome.

Example 1—Halting an Invading Army

Figure 4.1 shows a nomograph of the sort that we propose.[1] The top-right quadrant displays the value function for the case and objective under consideration (in this instance the first exemplar case defined in Chapter Two), relating important events to value of outcome for the objective. The bottom two quadrants have graphs showing how well capability needs are addressed by alternative approaches. In this example, there is no fourth graph, but the top-left quadrant can be used, as it is here, to define what is being addressed and the analytical case.

For a Southwest Asia scenario in which an invading army attacks south along the eastern Arabian coast, one measurable and recognizable metric for determining the value of outcome of "halting invading armies" is how far an enemy penetrated into friendly territory. (The application is just as valid as for a Korean scenario).

[1]These nomographs can be constructed many different ways. Different circumstances or analytic objectives might have led us to construct these nomographs differently. Likewise, other analysts may prefer alternative constructions.

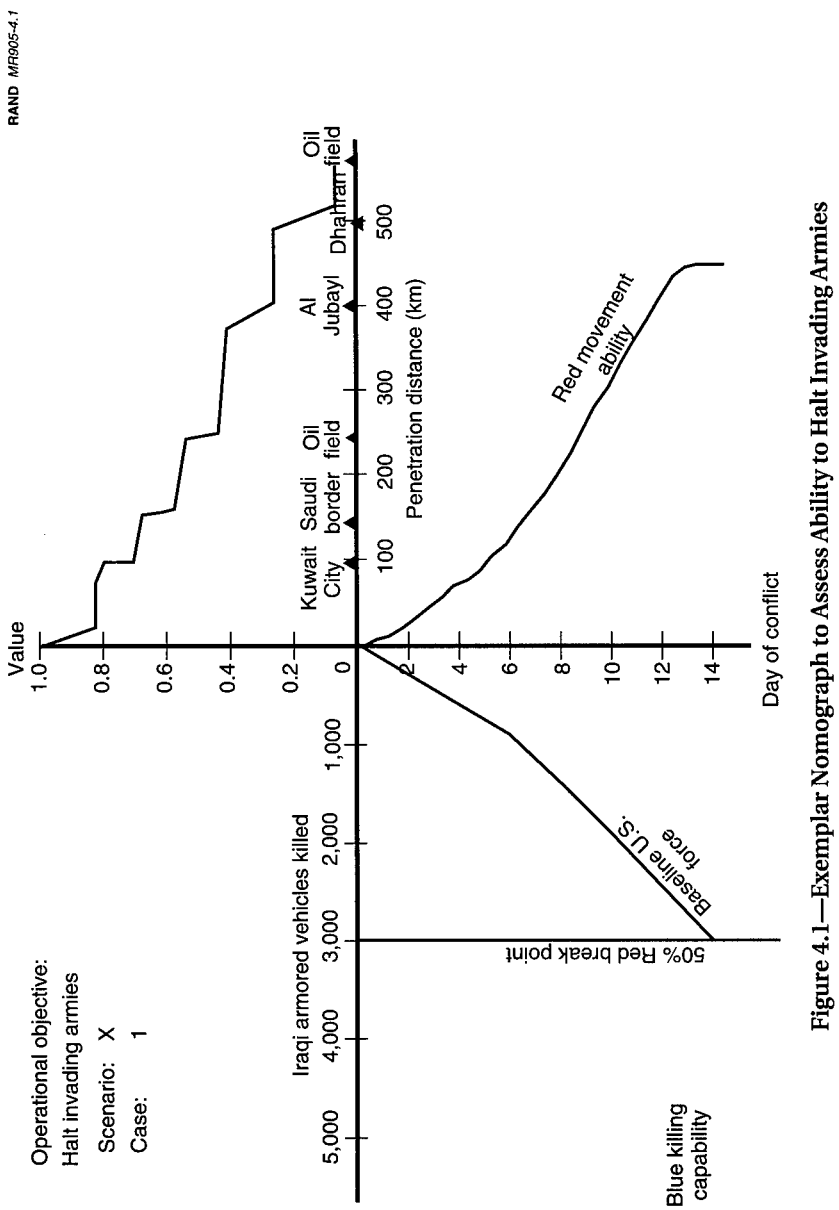

Figure 4.1—Exemplar Nomograph to Assess Ability to Halt Invading Armies

This value-of-outcome function is derived by strategists; the results are depicted in the upper-right quadrant of the nomograph.

In Figure 4.1, we plot the nominal rate of advance of the adversary in the lower-right quadrant. An enemy's advance potential is the function of many factors, including training, tactics, topography, infrastructure, obstacles, weather, and logistics. The resistance expected from U.S. and allied forces in the area is also taken into account.

In the lower-left quadrant, we display the ability of baseline U.S. and allied forces to act directly against the adversary's forces. In this example, we use estimates of the killing capability of these forces against enemy armored vehicles calculated using analytical methods at the engagement, operational, and campaign levels to determine how quickly enemy forces are drawn down.

The resulting drawdown curve is compared with estimates of the enemy "break point" to determine at what casualty rate the enemy forces will quit their advance. Enemy break points will be a function of many variables, including the quality of enemy troops and commanders, their operational doctrine, and other elements of enemy morale that will be difficult to determine and even harder to quantify. Part of the utility of using nomographs is that such factors as enemy break points can be assessed parametrically, and the impact of extremes determined—as will be shown in the next few pages.

The integration of these outputs enables evaluators to identify shortfalls or deficiencies in required capabilities against a desired outcome—and to determine if proposed concepts provide sufficient added value. In this example, it is desired to halt an invading army before it overruns critical areas or facilities. Perhaps a forward defense is possible, and the hope is to halt the enemy before it can capture Kuwait City. Halting the invading enemy army short of Kuwait City results in a value of outcome for this important objective of 0.9. The number 0.9 by itself is meaningless—it merely serves as an index. The value would have been 1.0 in this case if the enemy had been deterred from invading and not crossed the border. If the enemy captures all of Kuwait and Saudi Arabia, the value for this objective would be 0.

How quickly must the enemy advance be halted if it is to stop short of Kuwait City? Starting at the value axis in the upper-left quadrant at a value of 0.9, we move out to the value curve (as shown by the dashed line "1" in Figure 4.2 in the direction given by the arrows). We then move downward to the curve reflecting the estimated enemy advance rate. We then move to the left until we intersect the campaign metric curve at 4 days. How much damage can U.S. forces do in 4 days? We continue moving to the left to the curve in the lower left quadrant. We then move up to the performance curve of our baseline forces and find that they are expected to kill 600 enemy vehicles by day 4 of the conflict.

If indeed we believe that the enemy will halt when 600 of his vehicles have been killed, then we have succeeded. However, if we hypothesize that the advancing columns will not halt until they lose 50 percent of their armored vehicles then we will need to continue the attack longer. We can determine the implications of that 50 percent (~3,000 vehicles) by following the dashed line "2" in the opposite direction. We estimate that current U.S. forces will need 14 days to kill 50 percent of the enemy's vehicles. Unfortunately, at their estimated advance rate, the enemy forces might well overrun most of the places the United States values by day 14—resulting in an unacceptable outcome value.

Application to Force Modernization Alternatives. Evaluators can now use the nomograph to explore a range of alternative force modernization packages proposed by the conceivers to halt invading armies. Forces programmed in the Future Years Defense Plan (FYDP), or contained in service modernization plans beyond the FYDP, could be included in these packages. Conceivers enter their proposals on the lower-left quadrant of the nomograph, with the measure of effectiveness calculated as a function of the relevant campaign metric (time, in this case). The estimated capabilities of the modernized force packages are added to those calculated for the baseline forces and the improvement in overall military capabilities noted.

Adding the alternative modernization packages will change the character of the force. This changed nature might suggest that the force be employed in some completely different way. For example, consider the different ways that tanks were added to the French and

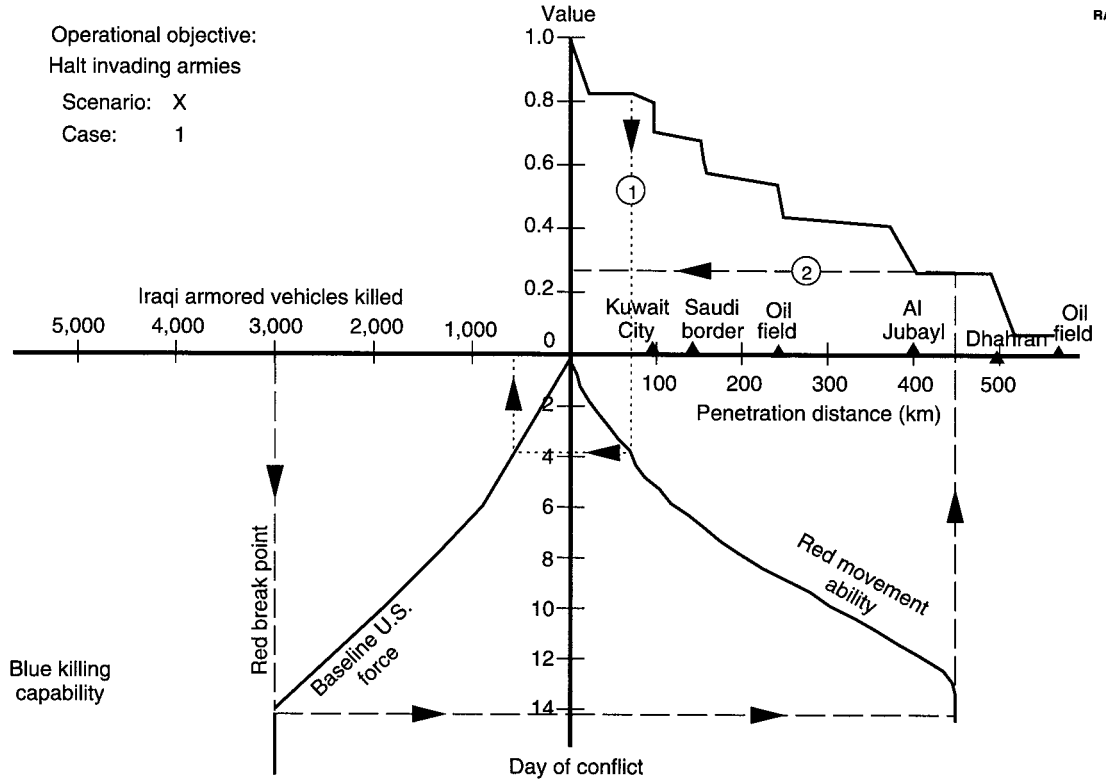

Figure 4.2—Outcome with Baseline Forces Falls Short of Desired Value

German armies before World War II. The French added them to infantry divisions, enhancing the firepower of the infantry, but not fundamentally changing its employment. The Germans, on the other hand developed a whole new doctrine and increased the tanks' effectiveness by concentrating them in armored divisions. It might well be that conceivers will develop some new operational concepts that will enable the operational community to wage a whole new type of war. The possibility that a whole new type of war can be waged must be an option explicitly available to them as the concepts are evaluated.

Because of the potential opportunities to invent a fundamentally new form of warfare, it is vital that the operational community play a large role in the evaluation process. Once the contribution of new operational concepts to modernized force packages has been estimated against the metrics of a particular nomograph, operators should think about how those concepts might best be employed. Different combinations of modernization options, new doctrine, and alternative campaign strategies can be explored to see where opportunities exist to gain an edge. Vulnerabilities of the modernized forces (and existing forces) should also be explored, and ways found by which the modernized forces might mitigate the threat.

As a first notional example, assume that a group of conceivers has developed a "blocking force" concept. This concept might insert some type of blocking force that can move into position quickly enough, with sufficient force, to make it impossible for the enemy to capture Kuwait City or move further. If this force can be effectively employed in time, then the result might be as shown in Figure 4.3.

If the blocking force is successful, then the invading army will be halted, even though it may not have yet reached the breaking point. The invading army may attempt to overwhelm the blocking force, and that must be considered. Alternatively, the invading army might attempt to "mask" and bypass the blocking force. The operators supporting the evaluation must consider how they would counter or exploit either enemy reaction.

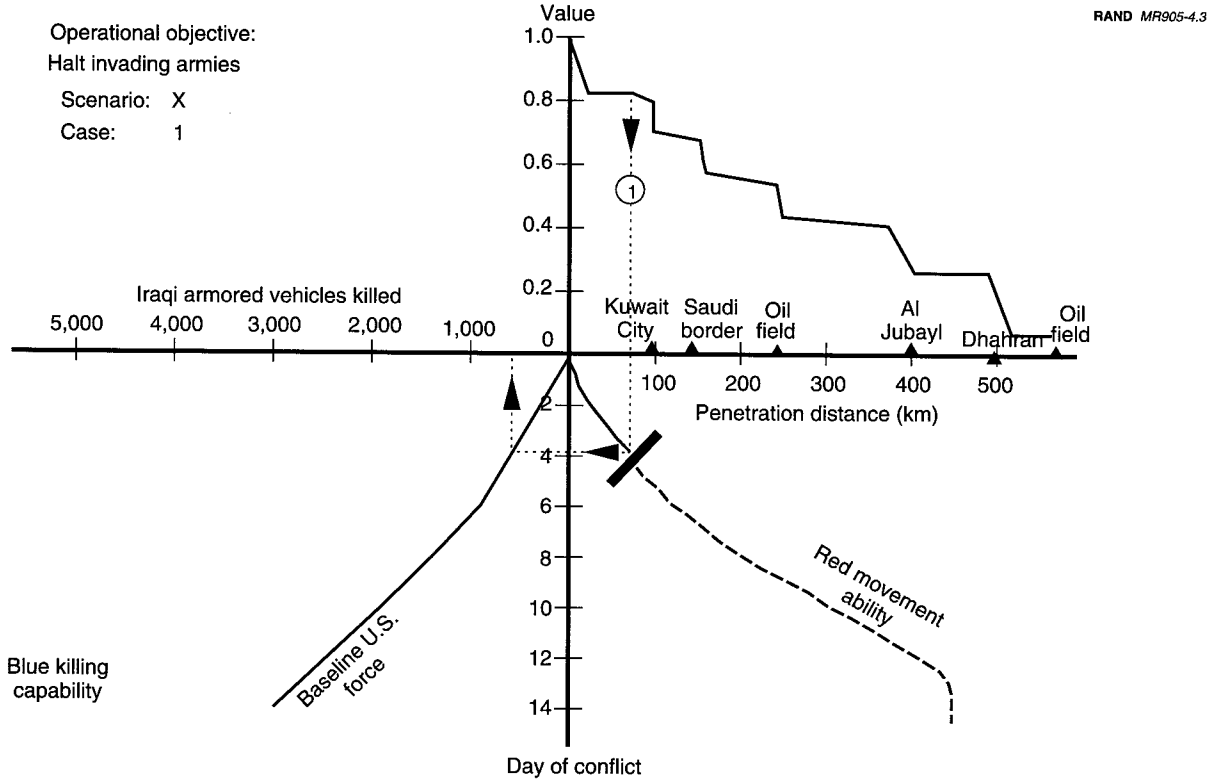

Figure 4.3—A Notional "Blocking Force" Might Stop Penetration at an Acceptable Outcome Value

Perhaps additional time can be bought by organizing a defense of Kuwait City proper, such that units might advance past the city but not actually take it (Figure 4.4). In this example, the enemy can penetrate further into Kuwait without causing much additional value loss—allowing more time for U.S. and allied forces to kill the lead elements of the invading army.

Perhaps also, some means can be developed to demoralize the enemy—or make his chosen operational concepts difficult to employ—such that he will have reached his breaking point after the loss of 10 percent or less of his force. In this way, the baseline force would have sufficient capability deployed in time to halt the advance (see Figure 4.5).

Alternatively, say that conceivers have developed concepts with the potential to drastically slow down the enemy. Perhaps the concept combines attacks against enemy logistics, transportation infrastructure, and key choke points, along with attacking advancing columns to force them to disperse off-road and laying minefields at carefully chosen choke points. Given an assumed killing capability, the more U.S. forces slow the advancing columns the less those columns penetrate—and the higher-value outcome is realized. In the ideal case, the enemy rate of advance would slow to the point where his break point would be reached before Kuwait City was taken (Figure 4.6).

Finally, conceivers might develop various ways to kill enemy armored forces more quickly (Figure 4.7). The goal is to cause the enemy to reach his break point before he has achieved his objectives. In this way, the enemy will lose his combat strength quickly enough so that he will be compelled to halt his advance before Kuwait City can be taken.

Figure 4.7 shows an ideal effectiveness increase sufficient to achieve the desired outcome value. How much of an increase might actually be expected from modernization packages already proposed? Killing capability can be improved, for example, by increasing the lethality of strike forces, speeding the arrival of additional strike forces to the theater, or improving the ability of strike forces to identify and target

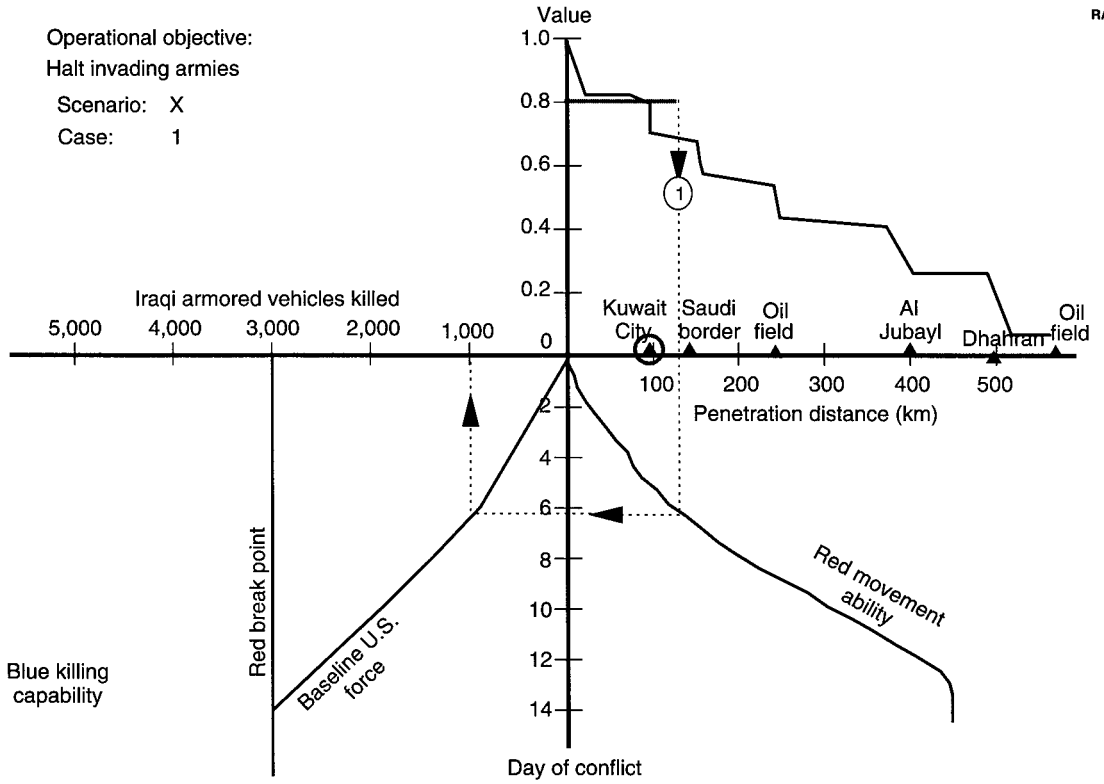

Figure 4.4—Defending Kuwait City Might Maintain Desired Outcome Level Despite Greater Penetration

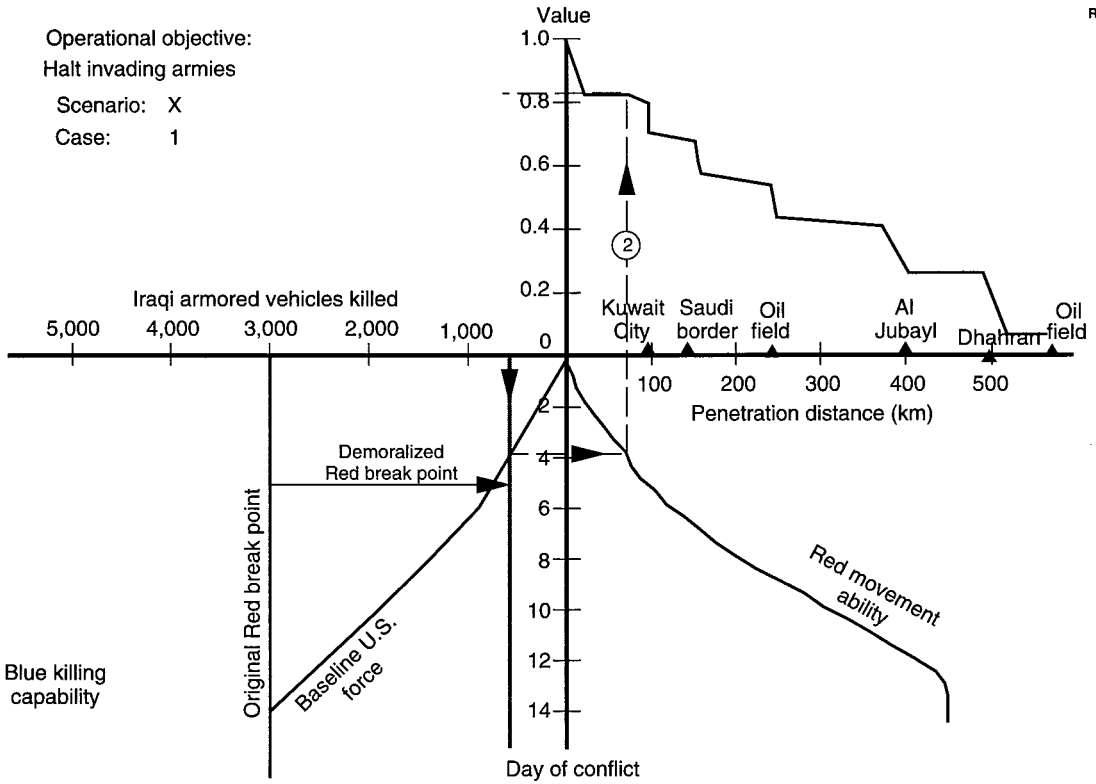

Figure 4.5—A Demoralized Enemy May Quit After a Small Number of Units Are Killed

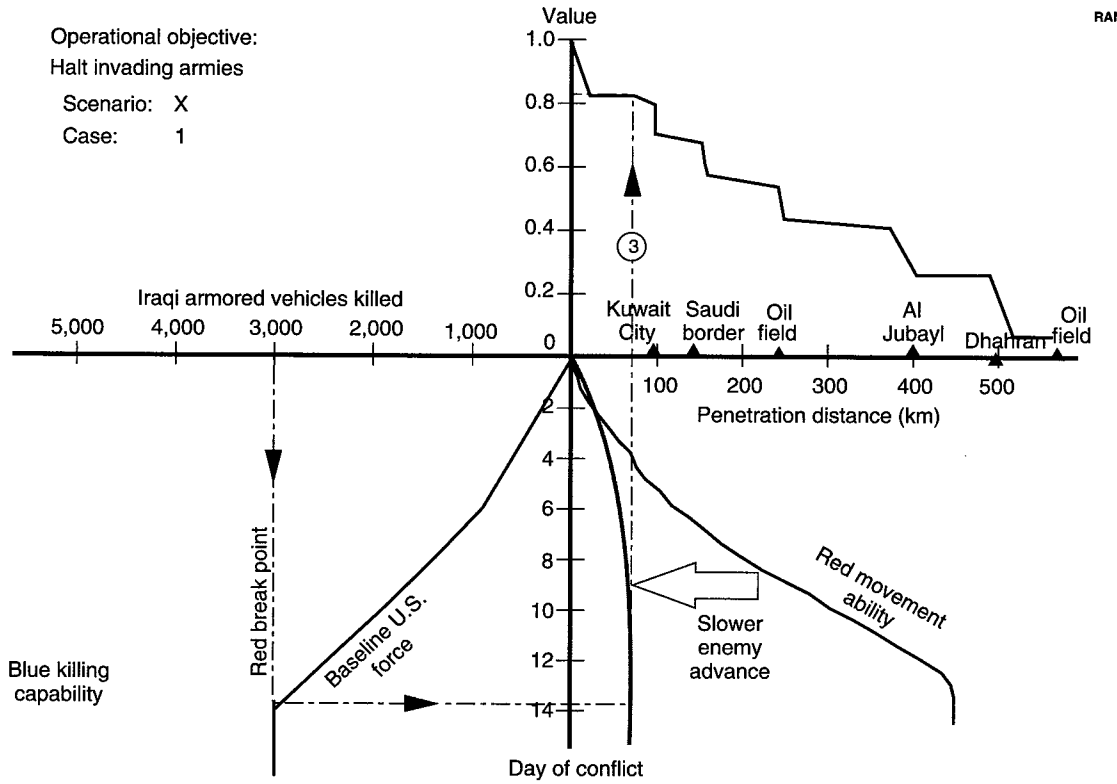

Figure 4.6—Penetration Might Be Contained by Slowing Enemy Advance

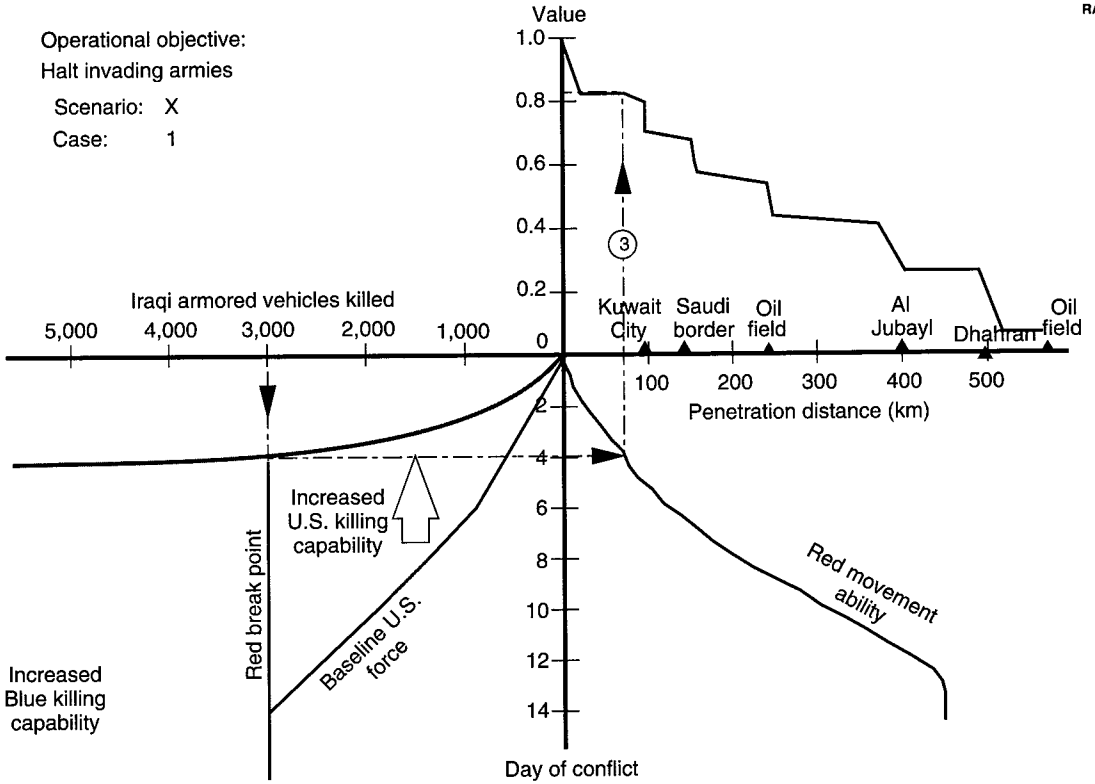

Figure 4.7—Increasing U.S. Killing Capability Can Cause Break Point to Be Reached Earlier

the highest-value elements of the invading army. In addition to destroying targets outright, the attacks themselves will help to slow the invading forces.

Some of those concepts have been explored in other RAND research, which organized them into four alternative force modernization packages. Here we represent these packages as A, B, C, and D (Figure 4.8).

The cumulative vehicle-killing improvements contributed by the modernized forces are shown in the lower-left quadrant of Figure 4.8. (It should be noted that these packages, of course, can be procured separately.) By helping the baseline U.S. force kill the advancing units more quickly, the force improvements will reduce the time that enemy forces advance before they reach their break point. The improvements will also likely have the additional impact of slowing the enemy advance—as shown notionally in the lower-right quadrant. The combined impact will be to minimize the harm that enemy forces do to outcome value.

If all the force modernization packages were acquired, then the enemy would reach its break point on day 7 and (moving along line 3 to the right) would have advanced only 70 km by that day. This would (moving upward) save Kuwait City from conquest—and result in an outcome value of 0.8.

Application to Enemy Countermeasures. What can the enemy do to disrupt the capabilities promised by modernized forces? Perhaps several things. Just as U.S. forces worked in the lower-right quadrant to mitigate the impact of invading forces by slowing their advance, so too might the enemy forces labor in the lower-left quadrant to mitigate U.S. ability to kill enemy armored vehicles. Again, the operational community must be asked to consider what the enemy forces might do to counter U.S. improvements.

For instance, as noted previously by other authors, the enemy might contrive to deny U.S. forces early access to the theater. Although U.S. units will likely be able to force entry, there might be a delay in deployment. The rightward-shifted curve in Figure 4.9 shows the reduction in killing capability from a six-day deployment delay. Operators might find ways to compensate—perhaps ending up with a

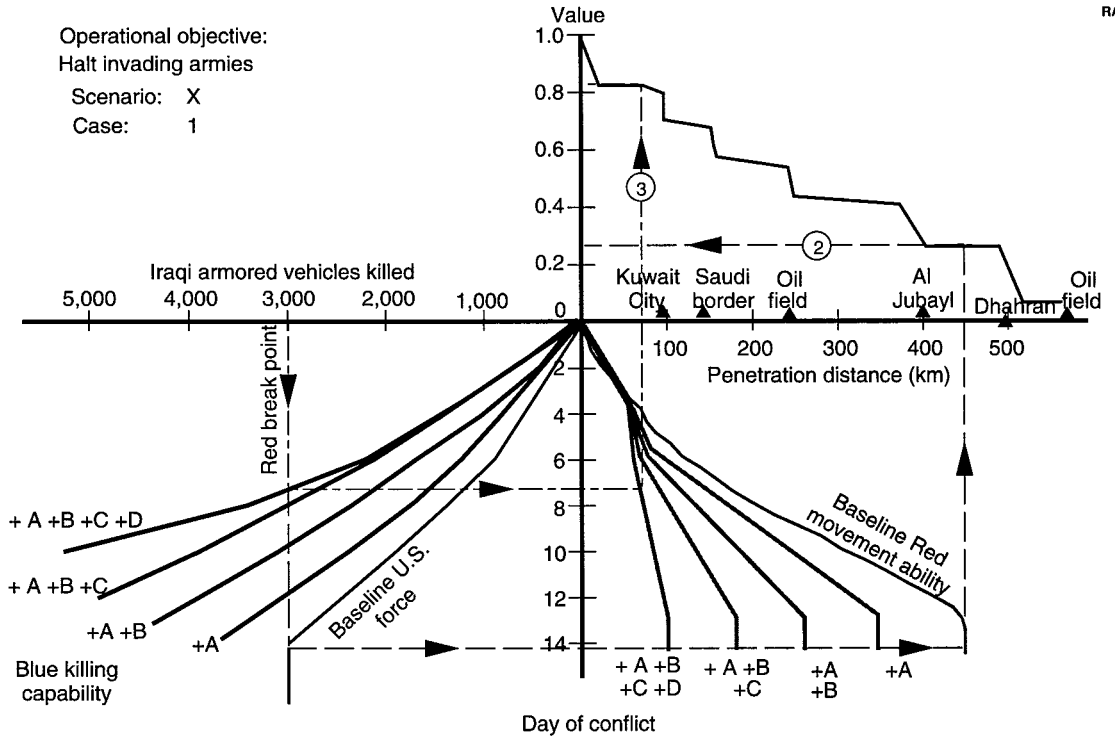

Figure 4.8—Combination of Slowing Enemy Advance and Increasing Killing Capability Can Help Achieve Desired Outcome Value

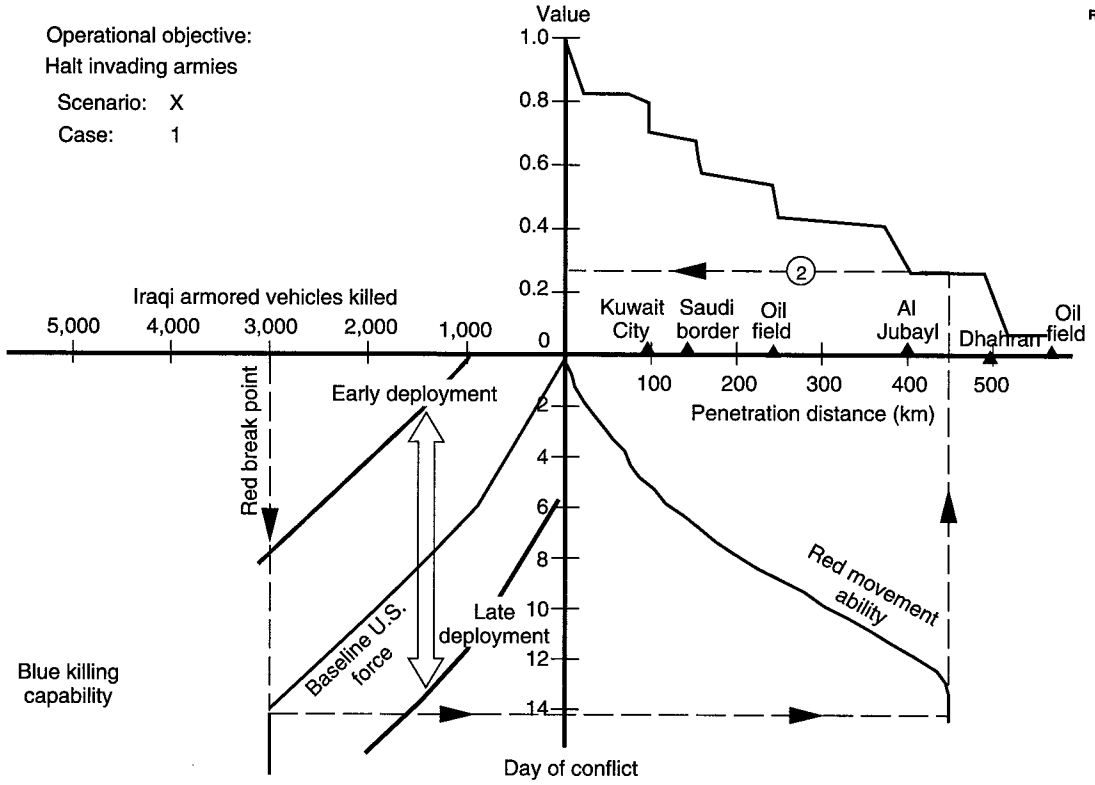

Figure 4.9—Early or Late Deployment Times Will Cause U.S. Killing Capability to Be Offset

killing curve as favorable as the leftward-shifted one shown in the figure.[2]

Alternatively, the enemy might attempt defending against some specific part of the modernized U.S. force packages. If a modernization includes arsenal ships, the enemy might employ some antiship concepts such as cruise missiles, submarines, mines, or attack boats to sink them. If the modernization concepts include more or better aircraft-delivered munitions, the enemy might consider improved integrated air defenses to deny deliverability of these munitions. New concepts, or improved doctrine, may be needed to "counter the counters."

Example 2—Neutralizing Enemy Air Defenses

The same general nomograph layout can be used to evaluate concepts intended to improve the outcome for other operational objectives. As a second example, the United States might want to suppress enemy air defenses in a contemplated contingency. It might be that this objective is in support of a larger campaign—like the one described above, where aircraft operations are vital to halting an invading army—or it might be to permit enforcing a no-fly zone, where operations are threatened by surface-based defenses.

In either event, let's assume it has been determined that current fighter aircraft, armed with planned weapons and escorted with planned SEAD aircraft, would operate at an unacceptable risk of loss against high-quality SAMs during the first 9 days of a campaign. In Figure 4.10, the value shown is in terms of potential attrition to U.S. aircraft on any given sortie. Again, we use *potential* attrition with the thought that U.S. tactics would change before *actual* attrition reached a high level. Attrition rate and the value associated with it are related to the percentage of SAMs committed by the line graphed in the lower-right quadrant. The percentage of SAMs committed is a

[2]Note: Early deployment would have the same curve shape only if enemy units were attacked *before* they crossed the border; otherwise killing would start on day 1 and be faster because there would be more U.S. units available.

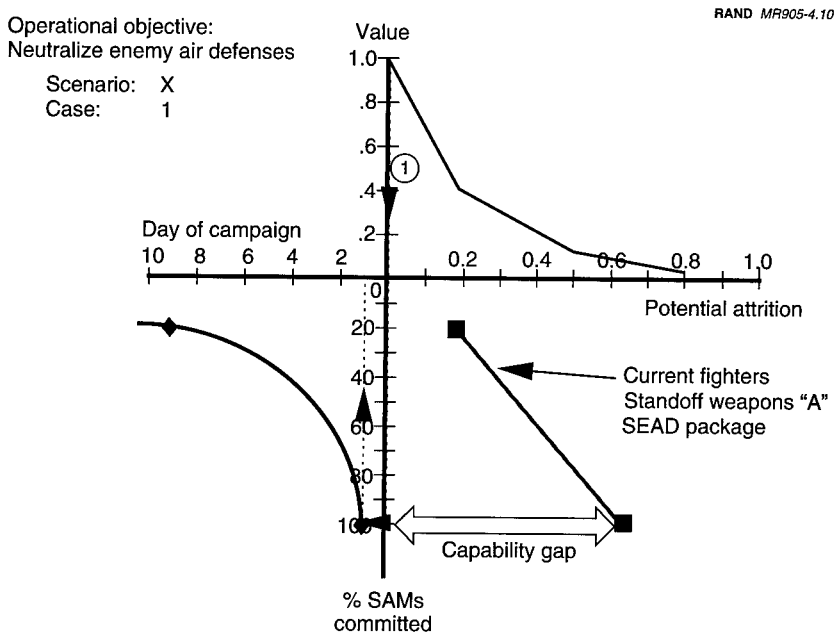

Figure 4.10—Exemplar Nomograph to Assess Ability to Neutralize Enemy Air Defenses

function of the progress of the U.S. SEAD campaign,[3] measured in days. That function is shown in the lower-left quadrant.

If we begin in the upper-right quadrant at our desired level of outcome (close to 1.0) and intercept our value curve, we find (by dropping down to the x-axis) that we can tolerate only a small potential attrition of our aircraft for this particular mission. Worse still, our exemplar baseline operational concept—combining aircraft platform, weapons, and SEAD escort—does not give us the ability to operate at this low level of attrition.

[3]It also depends on other factors that we do not consider here, e.g., how much of the SAM command and control apparatus is functional, which SAMs can use it, and which SAMs are emplaced (or capable of moving) to defend areas in which U.S. aircraft are to operate.

In fact, as shown in Figure 4.11, we find that on day 1 of the conflict we would suffer a very high potential attrition; with an unacceptable value of outcome resulting. (Of course, if the enemy chose to use few of his SAMs, or if they were broken or destroyed, the expected losses would decrease.) Even after the enemy SAM threat is reduced by our anticipated SEAD campaign, we find that on day 8 of the conflict our potential attrition is still too high.

What concepts might be considered to modernize force packages? Again, from past RAND research, we will consider three: improved fighter forces, stealthy aircraft, and a combination of longer-range standoff weapons and SEAD packages. The operational community would be asked to help evaluators consider the combination of these modernized forces with changes in tactics and doctrine. Perhaps improved fighters could operate at an acceptable risk of loss later in the campaign (after the SAMs had been put out of action), and perhaps stealthy platforms could operate with impunity from day 1. Alternatively, providing the existing forces with longer-range standoff weapons might reduce their risk of loss on day 1 to acceptable levels.

The result of these examinations might be as shown in Figure 4.12. A combination of existing aircraft, longer-range standoff weapons (standoff weapon "B"), and SEAD escort has moved the attrition-versus-SAMs-available graph far enough to the left so that a 9-day SEAD campaign could reduce per-sortie attrition to acceptable levels. If the United States were to use stealthy aircraft, for which attrition here is near zero even without a SEAD campaign, operations could get under way on day 1.

The manner in which a U.S. SEAD campaign is conducted is not specified here. It might be the cumulative result of kills made by the SEAD escorts for individual sorties, the result of dedicated SEAD aircraft sorties, or the result of attacks by sea or ground forces. As the SEAD campaign is made more effective, all of the U.S. concepts can be used with impunity (Figure 4.13). However, as the enemy manages to mitigate the effect of the SEAD campaign, the drawdown of his SEAD assets can be decreased, as shown in Figure 4.13.

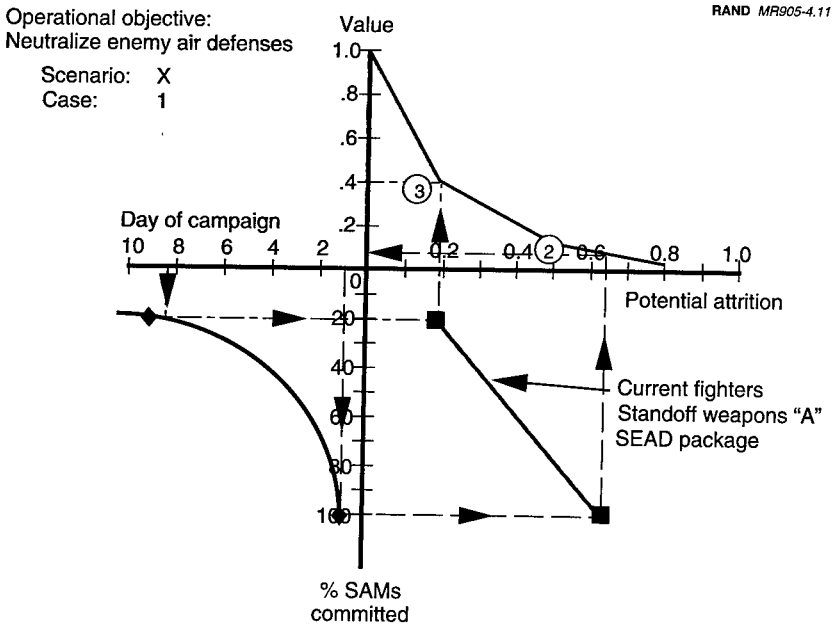

Figure 4.11—Current Fighters Have an Unacceptably High Potential Attrition Rate Against Very-High-Quality Air Defenses

EXTENDING THE ANALYSIS TO MULTIPLE METRICS

We think the nomograph approach proposed above will prove useful for integrating some important aspects of evaluation. It translates operational analysis into assessment of mission accomplishment, depicting the implications of U.S. force modernization packages and enemy countermeasures for achievement of U.S. operational objectives. However, not all important evaluation metrics are amenable to nomograph representation. Those not amenable include budgetary cost of the modernization packages, U.S. casualties, collateral damage to civilians and civilian facilities, damage to U.S. and allied installations, commitment of manpower resources, the opportunity

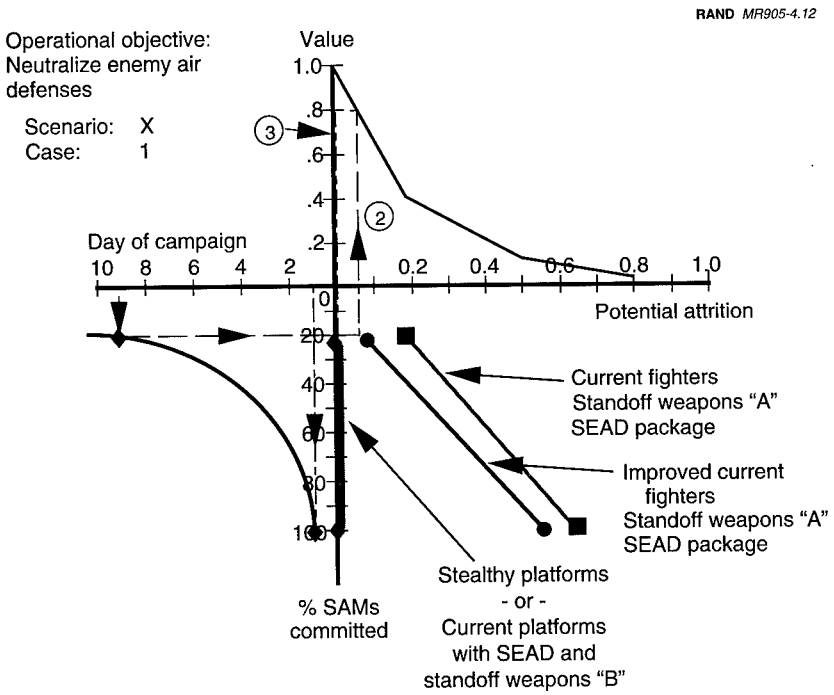

Figure 4.12—Alternative Force Packages Offer Lower Potential Attrition Against the Same Defenses

cost of weapon system use, and interoperability of modernized U.S. forces with allied forces. By combining the value enhancement information from the nomograph approach with that from other metrics, evaluators can provide top-level decisionmakers with a quantitatively sound basis from which to determine the allocation of resources most consistent with achieving a given objective.

One way of presenting information for the extended set of metrics is shown in the notional chart in Figure 4.14. Here, the idea is simply to identify the strengths and weaknesses of alternative concepts for accomplishing a given operational objective. We compare the four different concepts evaluated for halting invading armies. Some concepts that would be successful at halting invading armies, for instance, might do so at low expected U.S. casualty rates but at high

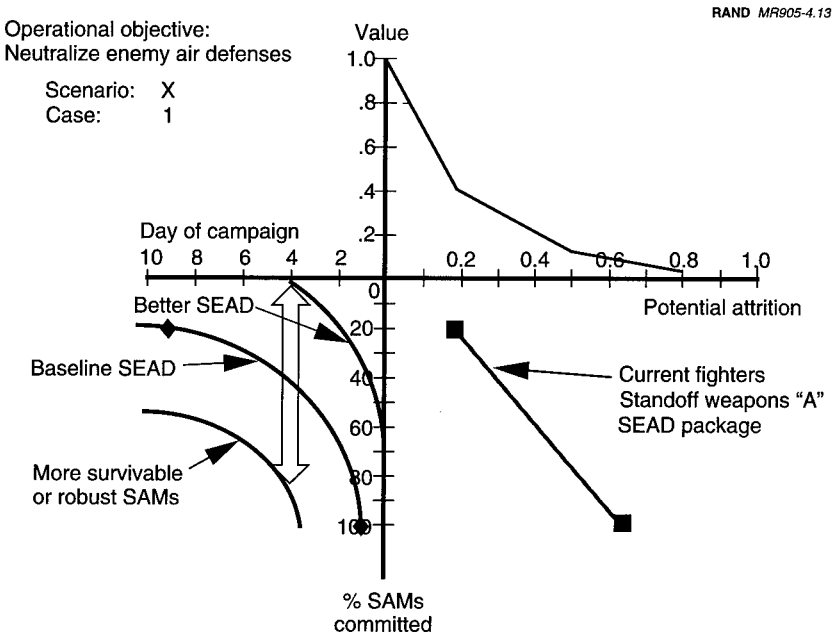

Figure 4.13—Alternatively, a More Effective SEAD Capability Might Be Developed—or the Enemy Might Enhance SAM Survivability

costs in materiel. Others might do so at high casualty rates but low costs of materiel. It is up to decisionmakers to weigh these trade-offs.

APPLICABILITY OF CONCEPTS ACROSS OBJECTIVES

Up to this point, we have considered the contribution of an operational concept to a single operational objective. An additional consideration is the applicability of a particular concept across a range of mission needs and regional conditions. Some weapons will contribute to many missions and objectives; hence, a cross-objective assessment must consider these weapons accordingly.

In fact, we may want new concepts that help shape the environment in theaters when there is no conflict, help win particularly tough

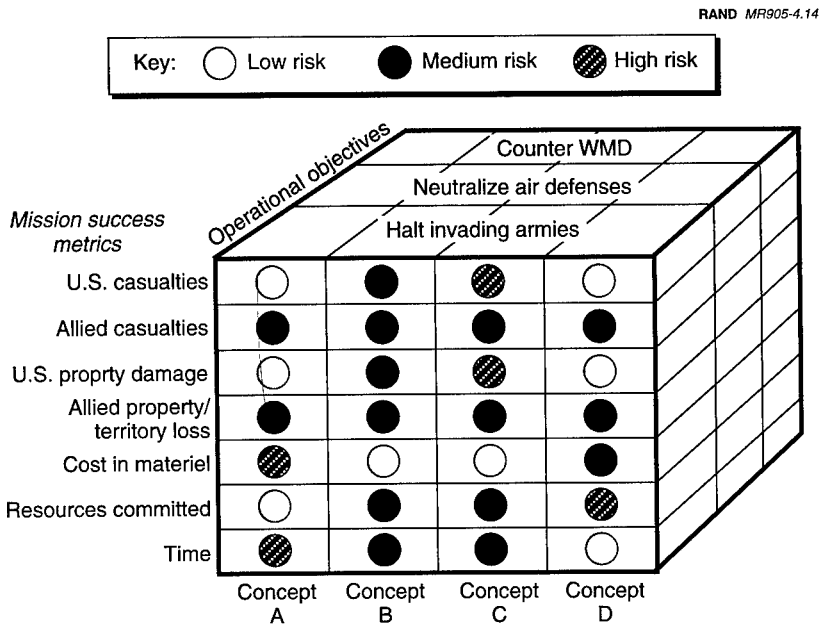

Figure 4.14—Alternative Force Packages Will Also Be Compared on the Basis of Costs and Broad Applicability Across Operational Objectives

major theater wars, and help prevail in less challenging conflicts.[4] Those concepts providing greater flexibility across a range of exigencies may offer a relatively better return on the investment made.

Cross-objective trades are necessary for the United States to maximize the efficiency of its force structure. In addition, these trades are necessary to address the massive uncertainty that exists in the conduct of each individual campaign. Depending on the actions of potential adversaries, any given mission may become a complex combination of different operational objectives to be achieved by U.S. forces. If those forces have a deficiency in achieving a given objective, then we may expect an adversary to exploit that weakness.

[4]See Davis and Kugler (1997) for a comprehensive treatment of the motivation for, and method of, force sizing.

Cross-objective trades will necessarily be made across a wide scenario space, and will examine many contextual, strategic, environmental, and force variables to address the uncertainty faced. Past RAND research has identified six categories that need to be considered in these examinations:[5]

- Political-military context (e.g., timelines, allies, access rights)
- Strategies (one's own and the enemy's)
- Forces (size and character)
- Force capabilities (nominal and real-world)
- Environment (e.g., weather, terrain, and urban development)
- Algorithms and related parameters used in the examination.

There are many possible combinations of variables in the above categories. One approach that ties together several such important considerations for the operational objective of halting an invading army in a Southwest Asia scenario is presented in Davis, Hillestad, and Crawford (1997). This approach relies on exploratory analysis, in which thousands of computer simulations are run to generate outcome matrices. An example given shows how the depth of an Iraqi armored penetration into Saudi Arabia is affected by the deployment date of U.S. forces, the Iraqi armored vehicles killed per Allied aircraft sortie, the percentage suppression of U.S./allied aircraft by chemical weapons attacks, and the access constraints placed on U.S. forces attempting to enter the theater.

Thus, a force modernization package that permits the deployment of more aircraft early in a conflict may stop an armored threat in the relatively easy cases, but perhaps not in the "bad" cases—when access is blocked, the Iraqis use WMD against U.S. air bases, and/or deployment starts late. Ultimately, top-level decisionmakers will decide which cases will drive U.S. force planning—the "worst case," or some combination of challenging but more-plausible cases. In addition, top-level decisionmakers will need to determine how to balance the baseline needs against the capabilities demanded by alternative missions.

[5]Davis (1994a); Davis, Hillestad, and Crawford (1997).

Chapter Five

DECIDING WHERE TO ALLOCATE MODERNIZATION RESOURCES

Top-level decisionmakers need to determine whether proposed concepts offer modernized forces within important policy parameters. These policy parameters are typically qualitative expressions of achieving national goals and maintaining national security interests and other enduring values of the United States. As the principal advisor on force modernization to the Secretary of Defense, the Under Secretary of Defense (Acquisition and Technology) (USD(A&T)) has a role in the decision process. Typically, resources are insufficient to fund all programs deemed necessary, and USD(A&T) may be called upon to help other decisionmakers trim the list of capability needs and concept proposals.

The samples of nomographs in the previous chapters provide a convenient tool to assist in some of the trade-offs that need to be made. For other assessments, qualitative judgment needs to be exercised. Take, for example, the cost of opportunity. What effect does spending resources on more-critical missions (e.g., national missile defense) have on the ability to perform important but less-critical missions (e.g., theater missile defense)? What are the overall force structure implications of certain concepts with respect to a total balanced force? What are the judgments about the relative importance of various missions and tasks across the spectrum of somewhat disparate responsibilities of the various regional CINCs?

Decisionmakers need to reassess whether the missions or operational objectives are indeed critical. They must also make trade-offs among metrics that evaluators illuminate. Is the risk of U.S. casual-

ties commensurate with the interests at stake? What will be the extent of collateral casualties and damage sustained by civilians and third parties? What is the cost of achieving the objective in terms of damage to U.S. and allied facilities, friendly territory lost, materiel destroyed, resources committed (and hence unavailable for other uses), and time needed? Assessments of these factors are needed to determine the nature and extent of any deficiencies in achieving an acceptable outcome for an operational objective.

The output of decisionmakers is a resource allocation strategy. If less funding is available than what is thought necessary, decisionmakers may need to trim the list of critical missions and objectives, eliminate selected deficiencies, or identify where to ask for more resources. Accordingly, decisionmakers can choose from the following list of alternatives:

- Buy more or improved versions of existing operational concepts to resolve deficiencies.
- Buy one or more new operational concepts.
- Determine that the value function is too demanding, and that a less stringent function more appropriately reflects the risk to U.S. security and interests and hence that a smaller or no deficiency in fact exists.
- Determine that either the mission, the operational objective, or both are not in reality critical and thus will be dropped from further examination.
- Determine that, although the mission and operational objectives are critical and there is a deficiency, the operational concepts proposed provide insufficient gain; hence, no opportunity to resolve the deficiency exists.

Chapter Six

CONCLUDING OBSERVATIONS

During our development of the nomograph approach, and our effort to integrate the results of other research on specific operational concepts, we gained insights into several difficulties with the current process:

- Although important missions are currently articulated by strategists, the value of alternative mission outcomes is not.
- Many offices within OSD evaluate modernization proposals from the services; but no one has taken the responsibility of systematically evaluating a wide range of concepts against the value of mission outcome.
- Those offices that do evaluate modernization proposals are typically asked to choose among hardware acquisition proposals, rather than among operational capabilities needed.

The framework provided by this research can help improve the current process. What is needed are several case studies in which important acquisition questions can be linked to desired improvement in the outcome of an important mission. Case studies such as these would demonstrate the utility of the framework, and provide a vehicle to refine and implement its features.

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